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An Electromyographic Study of the Behavior of the Masseter and Temporal Muscles Before, During, and After Orthodontic Treatment: Part VI. During Final Stages of Treatment

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AN ELECTROMYOGRAPHIC STUDY OF THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES BEFORE, DURING, AND AFTER ORTHODONTIC TREATMENT

Part VI. DURING FINAL STAGES OF TREATMENT

by

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LIFE

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CHAPTER I

INTRODUCTION

A. Introductory Remarks and Statement of the Problem

The aim of orthodontic therapy is not only to establish static "normal Occlusion" and acceptable dentofacial esthetics, but also it is concerned with the establishment, maintenance and restoration of the dynamics of the stomatognathic system. To achieve this end and to have a stable and lasting result, the teeth then, must be placed in a position that will be in harmony, not only with the supporting structures and temporomandibular articulation, but with the muscles that move the mandible as well and form the surrounding medium about the teeth.

It is a widely accepted fact that the musculature of the stomatognathic system plays an important role in the shape of the dental arches and in the stability of the occlusion. Since the site of some of the sensory receptors that influence the neuromuscular mechanism controlling mandibular movements is the periodontium, and since it is conceivable that orthodontic forces can change stimuli to the periodontal proprioceptors, it may be expected that this change can in some way influence the muscular behavior of the stomatognathic system.

The literature dealing with electromyographic studies of the function of these muscles is becoming more abundant every day, however, it cannot be disputed that more research in this field is needed to contribute to a more complete understanding of the function of the muscles of the stomatognathic system. Although some investigators have shown that changes in muscular behavior does occur as a result of orthodontic treatment Moyers (1949), Jarabak (1954-1956), Zwemmer (1955), Karau (1956), Ahlgren (1960), and others, few have attempted to investigate the change in neuromuscular function during the full spectrum of orthodontic treatment.

The purpose of this study is to investigate electromyographically the behavior of the temporal and masseter muscles before, during and after orthodontic treatment; that is, what effect, if any, does the change in sensory input due to the change in position of the teeth as a result of orthodontic movement have on the motor output to these muscles. The orthodontic procedures used in this treatment differ from other orthodontic methods in that light forces generated from highly resilient light wires and latex elastics were used, thus the forces were much lighter than those customarily obtained from an edgewise mechanism. This part of the study will compare the behavior of the temporal and masseter muscles during the final stages of orthodontic treatment with the behavior of these muscles prior to treatment. It is hoped that any neuromuscular changes in the behavior pattern of these muscles during this final stage of treatment may be detected.

This is a continuation of a longitudinal study begun by Widen, Asahino and Shanahan (1960) and followed by Zylinski and Fleming (1961).

B. Review of the Related Literature

1. Anatomy

It is generally conceded that a knowledge of structure must precede a study of function. A better understanding of the functions of the muscles involved in this study can only come after a basic knowledge of their anatomy and of the anatomy of the temporomandibular articulation. Most of the following material has been taken from Sicher (1960) and Gray's Anatomy (1960).

According to Sicher (1960): "All muscles that are attached to the mandible have an influence on its movements and positions." The mandibular musculature can be divided into two groups, the muscles of mastication and the suprahyoid musculature. The mandibular musculature thus upon the mandible either from the cranium or from the hyoid bone. Sicher states:

> Knowledge of the action of the individual masticatory muscle is a necessary premise to an understanding of their function during the movements of the mandible. These muscles, in conjunction with the suprahyoid musculature, work in groups as do other muscles in the body and not as individual units.

The four muscles of mastication are the masseter, the internal pterygoid and the temporal which exert their power in a vertical direction and are powerful elevators of the mandible, the fourth muscle, the external pterygoid exerts its power in a horizontal direction and protracts the mandible. All of these muscles receive their nerve supply from the motor portion of the trigeminal nerve through the mandibular division.

Since the masseter and temporal muscles are the ones that are being dealt with in this study, they will be described in detail.

The masseter muscle is thick and quadrilateral in shape, and consists of two portions, a superficial and deep, which are incompletely divided. The larger superficial portion arises by a thick tendinous sheath from the zygomatic process of the maxilla and from the anterior two-thirds of the inferior surface of the zygomatic arch. The fibers run backward and downward, to be inserted into the angle and the lower half of the lateral surface of the mandibular ramus. The smaller, deep portion arises from the posterior third of the inferior border of the zygomatic arch and from its whole medial surface. Its fibers pass downward and forward to inset into the upper half of the ramus and the lateral surface of the coronoid process of the mandible. The fibers of the two portions are continuous at their insertion.

The fan shaped temporal muscle is broad and radiating and is situated at the side of the head. It arises from the entire temporal fossa and from the deep surface of the temporal fascia. The fibers converge as they descend, and end in a tendon, which passes medially to the zygomatic arch and is inserted into the medial surface, apex and anterior border of the coronoid process of the mandible. This tendon also continues downward inserting on the anterior border of the mandibular ramus almost as far forward as the last molar tooth. Its most posterior fibers, because of their oblique direction downward and forward, have a retracting component.

The basic functioning component of muscle is a motor unit. A motor unit was first described by Sherrington and Liddell (1925) and later by Clark (1931) and by Best and Taylor (1958). It consists of an anterior horn cell and its axon or nerve fiber which divides into a varying number of branches and supplies a corresponding number of muscle fibers. Each axon branch of the motor nerve fiber loses its myelin sheath as it approaches the muscle fiber for which it is destined and terminates as a flat expansion on a specially organized structure known as the motor end-plate. This contact (there appears to be no actual union) is called the neuromuscular or myoneural junction. It exhibits many of the properties of the synapse existing between neurons. The ratio of muscle fibers to neuron in the temporal and masseter muscles may range from 1:110 to 1:165. In addition to the motor nerve supply, the motor unit has a sensory nerve supply.

As described by Best and Taylor (1958) and by Jarabak (1954) and (1957) the arrangement of the muscle fibers and the motor units in the muscle is in accordance with the function that the muscle performs. Thus, the fusiform and long strap like muscles have their fibers and therefore, their motor units, arranged in a chain or series so as to provide contraction over a great distance with speed. The quadrilateral or rhomboid muscle has its fibers and motor units arranged side by side in a parallel manner, thus providing great power over a shorter distance. The triangular shaped muscles have their fibers and motor units arranged so that the fibers pass from either side to a central tendon in an oblique direction. This arrangement is called bipennate (like a feather). In some muscles, only half of the "feather" is represented and is so termed unipennate. This arrangement provides both power and speed. Thus muscles of mastication are made up of combinations of these arrangements. Usually more than one arrangement being present in each muscle and sometimes as many as three.

The temporomandibular articulation is a ginglymoarthrodial, or sliding hinge joint. The parts entering into its formation are (1) the anterior part of the glenoid fossa of the temporal bone, (2) the articular tubercle above and (3) the mandibular condyle below and, (4) the articular disc interposed between the latter two. The joint consists of two separate cavities, each with its own synovial lining, the two cavities being separated by the articular disc. The ligaments that make up the joint, according to Gray's Anatomy (1961), are five in number: (1) the articular capsule, (2) the temporomandibular ligament, (3) the spheno-mandibular ligament, (4) the stylomandibular ligament, and (5) the articular disc. When the jaws are opened and closed, movement takes place in both parts of the joint; the disc glides on the articular tubercle, and the condyle moves like a hinge on the disc, causing the mandible to rotate about a center of suspension near the angle of the mandible. According to Gray's Anatomy (1961): "This somewhat moveable center is provided by the attachment of the sphenomandibular ligament to the lingula, and the sling formed by the masseter and the pterygoideus internus."

2. Histology and Histologic Background

Basically this study will deal with muscle and nerve tissue as related to the neuromuscular mechanism of the stomatognathic system and also, the periodontium, the site of certain sensory receptors that help control movements of the mandible during mastication. Therefore, some description of the histologic strucutre of these tissues and of the sensory receptors of the periodontal membrane, skeletal muscle and tendon is warranted in this discussion.

Skeletal or voluntary muscle as described by Maximow and Bloom (1952) has as its basic unit the muscle cell or muscle fiber. These muscle fibers are long and cylindrical in shape and taper at the ends to a point. The cell is multinucleated and is covered by the cell membrane or sarcolemma, it is thought to be the product of the cytoplasm. The muscle fiber is striated in the longitudinal and transverse directions. These striations depend upon the fact that the fiber consists of two parts: (1) the protoplasmic mass, or sarcoplasm and (2) thin cross striated fibrils, the myofibrils. The chief solid mass of the muscle fibers consists of several proteins, the most important of which are myogen, and actin combined with myosin. These are the contractile elements of the muscle. The nuclei are usually flattened in the direction of the long axis of the fiber, vary in number, and are usually found just beneath the sarcolemma. Myofibrils, under the electron microscope, have been found to consist of myofilaments. These myofilaments are thought to be the actin and the myosin.

Several combined muscle fibers form a primary bundle, and several primary bundles combined are called a secondary bundle and several secondary bundles combined are called a tertiary bundle and so on. A skeletal muscle then, is composed of muscle bundles varying in size and number. Between the fibers, inside the muscle bundle is a connective tissue covering called the endomysium, between the muscle bundles, the connective tissue covering is called the perimysium and the connective tissue covering of the anatomical muscle is the epimysium. Where a muscle is attached to a tendon, there is a close union of the muscle fibers with the collagenous bundles of the tendon.

The cells within the nervous system which carry out its special function are called neurons. The neurons, according to Maximow and Bloom (1952), have a body made up of a nucleus and surrounding cytoplasm, called the perikaryon. The cytoplasm of this cell expands into a number of processes usually comprising several short dendrites and only one axis cylinder or axon, which may have a great length. The relatively large nucleus has a thin, clear nuclear membrane, and in most cases a large prominant nucleolus. The cytoplasm of the cell body is called the neuroplasm in which is found, neurofribls, chromophile substance, mitochondria, golgi apparatus and various inclusions.

The nerve fiber, according to Best and Taylor (1952) is the elongated extention of a nerve cell, whose body is situated in the central nervous system or in an outlying ganglion. The peripheral nerves are nerve trunks and are made up of nerve fibers, often in great number, bound together in bundles. These bundles are made up very similar to the muscle bundles and the various connective tissue coverings are named endoneurim, perineurium, and epineurium, being analogous to the endomysium, perimysium and epimysium, respectively, of muscle. Each nerve fiber entering into the composition of the peripheral nerves consists of the axis cylinder and a fatty sheath called the myelin sheath. The layer of myelin enveloping the axis cylinder is enclosed in turn by a thin transparent, nucleated membrane, the neurilemma or sheath of Schwann. This myelin sheath is interrupted at regular intervals, and almost comes into contact with the axis cylinder. These constrictions are called the Nodes of Ranvier.

The proprioceptors associated with skeletal muscle are the muscle spindles, the golgi tendon organ, and the Pacinian corpuscles. Much of the following material has been taken from Fulton (1943), Granit (1955), Fulton and Rich (1960), and Best and Taylor (1958).

The muscle spindle, named by Kuhne (1863), and shown to be sensory by Sherrington (1894), was first described histologically by Ruffini (1892-1898). It is a complex of sensory end organs and muscle fibers which lie in the flesh substance of the muscle and embrace one or more modified muscle fibers called intrafusal muscle fibers.

The principal nerve ending spirals irregularly around the mid-portion of the intrafusal fibers and forms an annular band which is invested in a connective tissue capsule containing tissue fluid. The intrafusal fibers have motor innervation and possess a motor end-plate and a secondary "flower spray" sensory ending. These muscle spindles are found in all anti-gravity muscles, and in some flexors and are called the "stretch afferents". Mechanically they are in "parallel" with the muscle fibers and are affected if the muscle is stretched passively, if, however, the muscle contracts, the tension being maintained by the other muscle fibers; the spindle is not affected.

The golgi tendon organs or tension recorders, unlike the muscle spindle are affected whether the muscle is stretched passively or is actively contracting, as in either instance, the tension on the tendon is present. They are usually found at the musculotendinous junction at the ends of a muscle, well away from the tendons of origin and insertion. Each tendon organ is supplied by a single large myelinated nerve fiber which divides many times as it reaches the ending, each branch terminating as a fine spray of nerve endings that lie between the strands of tendon. The whole organ usually has a thin capsule.

The Pacinian corpuscles or end organs are found most commonly in tendon sheaths, and are endings of deep pressure sensibility. In structure they resemble an onion with concentric layers of fibrous tissue capsule and a knotted central fiber.

The periodontal ligament, according to Schour (1960) is the connective tissue which (1) fills the space between the surface of the root of the tooth and the wall of its alveolus, (2) surrounds the root occlusally from the border of the alveolus, and (3) supports the gingiva. Three layers of fibers may be distinguished, the alveolar fibers, the cemental fibers and the plexus intermedius between them. The fibers of the periodontal ligament assume a direction which corresponds to the different stresses placed on the tooth at various levels of its root. Black (1887) has classified them into: (1) free gingival group, (2) transeptal group, (3) alveolar crest group, (4) horizontal group, (5) oblique group and (6) apical group. The undifferentiated or mesenchymal cells of the periodontal ligament are multipotential in that they are capable of forming either bone, cementum or connective tissue. Most of the studies on the innervation of the periodontal membrane agree that the neural source is derived from the apical region and alveolar bone proper opposite the root surface. Descriptions of the mode of termination of the nerves of the periodontal ligament still differ from investigator to investigator.

The nerve supply, described by Schour (1960) is very rich in myelinated fibers. They enter the periodontal membrane with the blood vessels and follow the same course. As the nerves ascend gingivally, they give off terminal branches which innervate the stroma of the periodontal ligament.

Bernick (1957) using monkeys as well as human material, studied sections in which collagenous and precollagenous tissue had been removed by proteolytic enzymes prior to staining, thus, getting a much clearer picture of the nerves in the area which had been difficult to do previously because of the affinity of the staining material for collagenous material.

He stated that the nerves supplying the periodontal membrane arise from two sources: (1) branches from the dental nerve itself which innervates the periodontal membrane buccally, lingually, mesially and distally as they proceed gingivally, (2) from the interalveolar nerves which perforate the cribiform plate at various levels to unite with the ascending dental nerves. The combined nerve bundle proceeds gingivally and offshoots arise which end in the connective tissue of the periodontal membrane. Up to this point Bernick's findings are in general agreement with those of most investigators who have studied this area. The nerve fiber may pass in close proximity to the alveolar bone or cementum, according to Bernick. He also found: "At their peripheral endings they unite to form a fine arborization. From this delicate network, very fine filaments arise which finally terminate among the stroma cells, cementoblasts and cementum." These endings were not myelinated. He also observed medullated nerves in the membrane which upon losing their myelin sheath, terminated in an elongated spindle-like strucutre found mainly in the lower one-third of the root.

Many of the investigations carried out on the innervation of the periodontal membrane have dealt with the presence or absence of nerves and neural endings in the supporting structures of the teeth.

Dependorf (1913) reported definite endings of neurofibrils in the periodontal membrane. He described networks of neurofibrils ending in fine pointed processes in the cementoblastic region. Dependorf also described some of the neurofibrils of the periodontal membrane as entering the cementum and terminating in the cementoblastic layer.

Kadanoff (1936) observed neurofibrils ending in terminal plexi in which some of the fibrils had knoblike swellings. Kadanoff did not observe endings in the cementoblastic layer that Dependorf had reported. Kadanoff said that neurofibrils, which entered the cementoblast layer, looped back into the connective tissue of the periodontal membrane.

Van der Sprenkel (1936) reported the following in the periodontal membrane: (1)"End-rings", provided with a periterminal network, lying flatly on collagen bundles, individually inervated and situated near the alveolar wall, (2) terminal networks around connective tissue nuclei and (3) a nervous network from which nerve fibers go into the dentin to end in a very delicate ring inside the dentinal tubules. He postulated that these neural endings, both in the dentin and in the periodontal membrane were adequately stimulated by change in form corresponding with tension and pressure placed on the dentin and periodontal membrane respectively, during function. He stated: "Thus, the intradentinal endings collaborate with the periodontal endings in supplying the necessary stimuli for reflex regulation of the chewing mechanism."

Bradlaw (1936) supporting Kadanoff's findings also reported seeing terminal neural coils in the periodontal membrane appearing near the cementum and turning back on themselves after approaching the cementum.

He did not observe the neural rings reported by Van der Sprenkel.

Lewinsky and Stewart (1937) observed terminal networks in the periodontal membrane formed from the neural fibrils breaking up into fine arborizations. Many of these small terminal fibrils ended in small rounded bodies. These they concluded, on the basis of Stewart's work (1927) on pressure localization of the teeth, were probably receptors to pressure stimuli.

Rapp, Kerstine and Avery (1957) reported large neural trunks located centrally in the periodontal membrane passing gingivally, fine neural fibrils entering the periodontal membrane from the alveolar bone proper, running both apically and gingivally, organized, encapsulated neural terminations throughout the membrane, these were ovoid and consisted of interwaving fine neural fibrils, neural coils were observed along the surface of the cementum, other fibers passed toward the surface of the cementum but before contacting the surface, curved back into the periodontal membrane.

The investigations of Lewinsky and Stewart, Bradlaw and Bernick agree in that many neural bundles pass gingivally in the periodontal membrane in a location either near alveolar bone or along the cementum.

Rapp's findings disagree with these in that he states that the neural bundles are located centrally in the periodontal membrane. The fact that neural fibrils enter the periodontal membrane from the alveolar bone proper was shown by almost all investigators. Lewinsky and Stewart, Bradlaw, Kadanoff and Rapp all agree that upon approaching the cementum, the neural fibrils turn back on themselves and end in the periodontal membrane. Only Bernick and Dependorf and Van der Sprenkel reported seeing these neural fibrils entering the cementum. Rapp was the only investigator that reported seeing encapsulated neural terminations throughout the periodontal membrane.

Brashear (1936) in demonstrating nerve fibers of all sizes in the periodontal membrane concluded that there is good reason to believe that through its supply of nerve fibers of all sizes, the periodontal tissue becomes the organ of touch of the tooth, as well as responding to other stimuli.

3. Physiology of the Neuromuscular Mechanism

An understanding of the reflex nature of the neuromuscular mechanism controlling mandibular movements during mastication is essential in any investigation attempting to evaluate the adaptability of certain masticatory muscles to a change in tooth position, or, as it were, a change in sensory input.

Much of our understanding of the function of the central nervous system and muscular co-ordination has its basis in the early work done by Sir Charles Sherrington.

Sherrington (1906) described the reflex arc as consisting of a receptor, conductor and effector, and as being "the unit mechanism of the nervous system when that system is regarded in its integrative function."

Creede (1932) described a simple reflex arc as consisting of:

> The inward parth, which is composed of a receptor organ connected to an afferent nerve-fiber. Afferent nerve-fibers enter the spinal cord by the dorsal roots.
>
> The nervous (or reflex) center in the central nervous system.
>
> The outward path, composed of an efferent nerve-fiber and an effector organ, e.g., muscle or gland. Efferent nerve fibers leave the spinal cord by the ventral roots.

"Co-ordination, therefore," said Sherrington, "is in part the compounding of reflexes."

Hering and Sherrington (1897) obtained by electrical excitation of the appropriate centers of the cerebral cortex of monkeys and cats, some remarkable instances of, what Sherrington termed, "reciprocal innervation". They found that upon excitation of the appropriate focus in the cortex an immediate relaxation of the extensor muscles occured with a corresponding contraction of the flexor muscles. This pointed up the fact that the central nervous system is organized, not in terms of anatomical segments, but in movement patterns. It is this phenomenon that makes possible the smooth, co-ordinated movement of limbs and body and also governs the speed and smoothness of movements of the mandible during mastication.

Sherrington (1906) in a paper on the proprioceptive system classified the sensory receptors into three groups: (1) the extroceptors, which receive stimuli from the external environment of the animal (the special senses such as sight, smell and hearing are classified as teleceptors as they perceive stimuli at a distance), for instance heat or cold, (2) the interoceptors, which receive stimuli from the internal environment of the animal, or alimentary environment such as the gastrointestinal tract, and (3) the proprioceptors, or receptors which lie in the deep tissues and are adapted for excitation by changes in the organism itself and give a sense of position and bodily movement in space. These receptors are found in the skeletal muscles and their tendons, in joints and in the labyrinthine sense organs. Sherrington described the cerebellum as "the head ganglion of the proprioceptive system", through which all proprioceptive impulses are apparently integrated. It is this proprioceptive system that governs posture or bodily attitude and imparts smooth function to reflex movements. Certain proprioceptors such as those in the periodontal membrane seem to have an early protective purpose.

Sherrington (1898) described "decerebrate rigidity" and pointed out that this indicated that tonus was not distributed indiscriminately in limb muslces of all vertebrates but that it occurred most markedly in the muscles that counteract the action of gravity. He described the decerebrate preparation as "an exaggerated caricature of reflex standing, the limbs are vigorously extended, the jaw tightly closed by the masseters and the tail extended". The exaggerated extensor response which Sherrington described is now known to be due to the stretch reflex or myotatic reflex, which is mediated through the receptors (proprioceptors) lying in the muscle itself, the muscle spindles.

Sherrington (1917) in working on jaw reflexes of the cat, was able to evoke regularly, with blunt pressure, the opening of the jaws upon stimulation of the gums and the teeth of both jaws and the front part of the hard palate. This reflex was also evoked by stimulation of the proximal segment of the cut afferent superior alveolar nerve. Thus, it is seen here that the removal of central inhibition by removal of the cerebral cortex causes reflex closure of the jaws due to myotatic reflexes and reflex opening due to the application of a noxious stimulus much like the ipsilateral flexion reflex obtained in a limb. Here, then, is an example of the compounding of reflexes into the co-ordinated masticatory movement.

Sherrington said: "the jaw reflex under a series of repetitive stimulations results in a masticatory movement, the openings of the jaw occurring with the stimulations, the closings by strong rebounds between the stimulations".

Denny-Brown (1929) using the string galvanometer observed that as the stretch stimulus on a muscle was increased more and more motor units came into play. The seconday and tertiary action currents arising from additional anterior horn cells.

Adrian and Bronk (1929) corroborated Denny-Brown's findings. They obtained action currents from single units in muscles, but instead of using the stretch reflex as did Denny-Brown, they used microdissection of the motor nerve to the muscle, thus, they were able to isolate two or three fibers, the remaining fibers being sectioned. Their observations indicated that the stronger the stimulus, the more rapid the rate of discharge of the motor units, therefore, it can be seen that here is another mechanism for gradation of the speed and smoothness of the contraction of skeletal muscle.

Allen (1919) showed that the mesencephalic trigeminal root contained both ascending and descending fibers. The ascending fibers have their origin from sensory cells in the semi-lunar ganglion, and the descending fibers from globular, unipolar cells in the alar (sensory) plate of the mesencephalon, and from the caudal continuation of these cells which extend downward into the motor area of the pons. These two groups of mesencephalic root fibers join upon entering the pons to form the mesencephalic root or tract. He felt that the ascending mesencephalic root fibers were mainly sensory but contained some muscle sense fibers and that the descending mesencephalic root fibers were concerned mainly with muscle sense. It was stated that many fibers and collaterals from both the ascending and descending mesencephalic root fibers went to the trigeminal motor nucleus and to a group of small cells situated medial and dorsal to the trigeminal sensory nucleus. "The former", Allen said, "evidently form reflex arcs with the motor cells and the latter may be a muscle sense relay station to the cerebral cortex." It is in this manner that the impulses from proprioceptors in the masticatory muscles and their tendons, temporomandibular joints, and periodontal membrane can be mediated through reflex arcs or pass on to higher centers in the brain. Thus, the masticatory mechanism can be reflexly or voluntarily controlled.

Pfaffman (1939) confirmed the fact that the periodontal membrane is richly supplied by nerve endings, which are sensitive to mere pressure or touch. He also found that pressure thresholds of the teeth before and after removal of the pulp is little changed as measured from action potentials obtained from the cut end of the superior alveolar nerves. He also noticed sudden movements of the mandible on sectioning of these nerves. He demonstrated unidirectional sensitivity of the periodontal endings, which is the basis for accurate localization of the stimulus applied to the tooth, as shown by Stewart (1927). The fact that a rich tactile response may be obtained after destruction of the apical nerves agrees with the histologic findings that the majority of the nerves to the membrane come from the alveolar plate itself (Lewinsky and Stewart, 1937, Van der Sprenkel, 1936, Bernick, 1957 and Rapp, 1957). Pfaffman further related the extreme development of the pressure sensitivity, which he demonstrated, to the reflex control of mastication. As Sherrington (1917) demonstrated reflex opening of the jaws to pressure stimuli, so did Pfaffman using faradization of the central end of the sectioned alveolar nerve.

Corbin and Harrison (1940) and Corbin (1940) working on the peripheral distribution of those fibers arising from the mesencephalic nucleus of the trigeminal nerve considered the larger cells of the mesencephalic nucleus to be the cells of origin of the afferent fibers of alveolar and palatine nerves concerned in the reflex control of mastication. They demonstrated electrical activity from the mesencephalic tract when the masticatory muscles were stretched passively by depression of the mandible. They concluded that the pressure sensations elicited from the periodontal membrane, and muscle and tendon proprioceptors of the jaw would then serve to control the force of the bite, preventing damage to the teeth, gums and palate. They said that impulses arising from the teeth, gums and palate would then, not only inhibit activity of the mandibular elevators through the inhibition of the motor nucleus of the trigeminal, but also actively elicit jaw opening through reflex stimulation of the motor nerves supplying the mandibular depressors. They state that the physiological evidence of Sherrington (1917) and Pfaffman (1939) in conjunction with their anatomical findings, suggest that the mesencephalic root fibers to the periodontal membrane and palate and those to the muscles of mastication serve to control the force of the bite as a protective measure and also reflexly control mastication.

Szentagothai (1948) using the "bouton degeneration method" traced the processes of the mesencephalic tract neurons to their termination in neuromuscular spindles of the masticatory muscles (especially in the temporal and masseter muscles) as annulo-spiral and flower spray endings. Before joining the motor root of the trigeminal, he found these processes to give reflex collaterals to the motor ganglion cells of the trigeminal motor nucleus, thus forming a two neuron reflex arc of the masticatory muscles. He was also able to trace some reflex collaterals from these processes to the motor nuclei supplying the infrahyoid muslces, which are the antagonists of the masticatory elevators. On compaing his results with those of Corbin and Harrison (1940) he was able to conclude:

(1) that this was the first anatomical evidence of the monosynaptic short reflex arc of stretch reflexes postulated by neurophysiologists, (2) it was proof of the stretch afferent function of the neuromuscular spindles, (3) that monosynaptic reflex arcs are reserved strictly for mediation of the stretch reflex and (4) it is morphological evidence of the existence of direct inhibitory collaterals from stretch afferents to motoneurons of the respective antagonists.

Pearson (1949) in a study of the development of the mesencephalic root of the trigeminal in human embryos supported the findings of earlier investigators Allen (1919), Corbin (1940), Corbin and Harrison (1940) and Pfaffman (1939), in that, the connections of the fibers of the mesencephalic root of the trigeminal with the motor nucleus of the trigeminal and other motor nuclei of cranial nerves form a direct reflex pathway for co-ordinated movements of the jaw muscles. However, he felt that the unipolarity of the cells of the mesencephalic root had been over-emphasized by many authors, leading to a limited concept of the connections and functions of this system of fibers. Pearson found many bipolar and miltipolar cells of the mesencephalic nucleus after birth and outlined the connection of their fibers into the optic tectum and the nuclei of the third, fourth, and (motor) fifth nerves, cerebral hemispheres, vermis and centers in the medulla oblongata.

Matthews (1958) showed electromyographically that rather than being due to a constant motor discharge the stretch reflex was a true reflex.

The concept of inhibition had its origin in the discovery of Weber and Weber (1845) when they demonstrated that stimulation of the peripheral end of the vagus nerve caused temporary cessation of the heart beat. A search for inhibitory nerves to skeletal muscle was precipitated by many investigators, however, no inhibitory nerves were ever found to the skeletal muscles in vertebrates. It was widely concluded that inhibition must be a central process, and so the term "central inhibition".

Fulton (1943) said ". . .as far as skeletal muscle is concerned inhibition means mere cessation of activity. If a motor nerve could be instantaneously severed without stimulation, its status would be precisely similar to that of having its ventral horn cells inhibited centrally."

Weiss (1950) in doing recombination experiments by transplantation of muscles and reversal of limbs in frogs and salamanders concluded that:

> The very fact, that the transplanted muscles contracted in accordance with their names rather than their positions, proves that co-ordination patterns are determined centrally,

and that the central patterns, though normally reinforced by proprioceptive reflexes, take precedence over the latter under conflicting circumstances.

Jarabak (1954) concisely summarized the function of the neuromuscular mechanism in controlling jaw movements:

> In addition to the motor nerve supply, the motor unit also has a sensory nerve supply. The sensory nerves carry messages from the muscles back to the central nervous system; thus, in a sense they serve as a "feed-back" mechanism advising the central nervous system (most generally on a subconscious level) of what is taking place in the individual motor units of the contracting muscles. This feed-back mechanism is known as the proprioceptive system. Structurally, the sensory feed-back system leading to the central nervous system has four types of nerve endings or receptors; two of them are situated in the substance of the muscle fibers of the individual motor units, and two are in the fascia and tendons. Generally speaking, some of the receptors found in the muscles send sensory impulses to the sensori-motor cortex (Gay and Gellhorn, 1949) when the muscles are passively stretched while others are activated both by muscle stretch and by muscle contraction. Functionally this feed-back system acts in a 'braking' or inhibitory capacity, guiding the degree of contraction within the motor unit.
>
> In addition to the proprioceptive mechanism found within the substance of the motor units, the muscles of mastication are under the control of still another feed-back system whose receptors are located in the periodontal membranes and gingivae surrounding the teeth and in the mucosa in the floor of the mouth. Through these receptors sensory stimuli of touch and pressure arising from the articulation of the teeth are conducted first to

the mesencephalic nucleus where a reflex arc may be formed, or they may continue from here to higher brain centers in the cortex. Thus, it is conceivable to visualize that a change in the proprioceptive stimuli originating in the teeth, caused by a malocclusion, may change the pattern of function of the muscles attached to and responsible for the movements of the mandible.

4. Electromyographical Background

Electromyography is the recording of electrical changes which occur in an anatomical muscle or portion of that muscle by means of an electrode placed on the skin over the muscle or by a needle electrode inserted into the muscle through the skin. Since the muscle fibers of the muscle represent a much larger volume than do the nerve fibers (motor) and motor end-plates, the recordings represent only the potential changes of the muscle fibers.

The subject of muscle generated electricity was first opened by Redi in 1794. In 1851 DuBois-Reymond registered action currents from the contracting arm of a man. Lippman (1872) invented the capillary electrometer which was used for recording tissue potentials. Piper (1907) and Buchanan (1908) recorded voluntary contractions of the flexors of the forearm of man using the string galvanometer and the capillay electrometer respectively. Lucas (1909) stated the "all or none" principal when he noticed that the degree of contraction of muscle increased in steps as the intensity of stimulation increased, but that the number of steps is never greater than the number of nerve fibers supplying the muscle. Hill (1921) described action potential as a minute fraction of the total energy liberated when a muscle contracts. This energy that appears as electrical energy is picked up and recorded by the electromyograph.

The actual electrical potential produced by muscle is thought to result from changes in polarization of the cell membranes. Thus, when a stimulus is applied to a somatic nerve, a progressive wave of depolarization continues along the nerve to the muscle. At the myoneural junction the nerve action potential sets up an end-plate action potential or spike potential by depolarizing, to a critical level, the muscle membrane around the junction (Fulton, 1955).

Clinical electromyography was begun by Proebster (1929) when he obtained tracings in peripheral nerve paralysis. Others followed, and applied electromyography to clinical usage in pathologic conditions; Lindsley (1935), Denny-Brown and Pennypacker (1938), Denny-Brown and Nevin (1941), Bucthal and Clemmesen (1941), and Hoefer (1941). In 1944

Weddell, Feinstein and Pattle published a complete report on clinical electromyography.

Moyers (1949) was the first to introduce electromyography into dentistry. His work published in 1949 was actually done after the work published in 1950. Moyers (1950) using unipolar surface electrodes and needle electrodes, with the ear lobe as the reference, showed the normal spike potentials for the various muscles of mastication and for the suprahyoid muscles. He showed that mandibular depression was brought about by contraction of the external pterygoids and the anterior bellies of the digastrics. Elevation of the mandible was brought about by co-ordinated action of the medial pterygoids, masseters and temporals. He also showed protraction was a result of simultaneous contraction of the lateral pterygoids and retraction by the middle and posterior fibers of the temporals. He pointed out that the suprahyoids act as stabilizers in many of these movements. He was also able to demonstrate changes in muscle pattern from the time of the deciduous dentition to adult hood.

Moyers (1949) considered the role of temporomandibular musculature in the genesis of Class II (Angle) dento-facial deformities. He took recordings before and after treatment and tried to determine if the muscular pattern was the etiology or the result of the dental facial deformity. He concluded that:

> No Class II, Division I showed normal spike potentials from temporomandibular musculature.
>
> Orthodontic therapy can alter spike potentials.
>
> Aberrations in muscle patterns can result from malocclusions.
>
> Inherent deviations from normal can indicate muscle function as an etiologic factor.

Moyers' findings have important implications in orthodontic treatment, for in many Class II cases there may be a distal positioning of the mandible and in treatment, the mandible, therefore, should be brought forward into its normal position to establish the correct molar relationship rather than an enmasse distal movement of all the maxillary teeth.

Carlsoo (1952) using autopsy material and anthropometrics deduced the mechanical function possible by the muscles of mastication and the extent of possible movements of the temporomandibular joint. Then using electromyographic techniques on live subjects he mapped the muscular patterns associated with the different mandibular movements. As Moyers did, Carlsoo determined the roles played by the different masticatory muscles. He found that the temporal played the most important role in habitual rest position and in habitual closure of the mandible. Carlsoo further stated:

> The electromyographic investigation demonstrates that certain differentiated innervation patterns show a close agreement between the activation of the muscle portions and their mechanical qualifications. The distribution of muscular activity, however, is not in direct relation to their relative mechanical potentialities. Therefore, the distribution of the muscular activity cannot be deduced from a knowledge of mechanical qualifications only, nor according to the principle of reciprocal innervation alone.

Sicher (1954) in a discussion on positions and movements of the mandible stressed the following point:

> The electromyograph registers the action potential of a muscle; that is, it shows when and how strongly a muscle acts, but it does not and cannot show in which capacity the muscle activity occurs. Muscles can contract isotonically or isometrically. If they contract isotonically, they shorten and retain tension; if they contract isometrically, they tense but do not shorten and thus retain their length. By isotonic contraction muscles act as movers, by isometric contraction they act as holders, stabilizers, positioners.

Pruzansky (1952) reported on findings concerned with the mapping of electromyographic patterns of certain facial muscles including the muscles of mastication. He demonstrated synergistic behavior of the muscles of mastication during functional movements of the mandible and showed how the patterns differed with respect to certain disturbances in occlusion, and felt that these differences may be correlated with the efficiency, or lack of efficiency, of the masticatory mechanism. He found synchronous discharge of the temporal and masseter on the ipsilateral or working side in normal occlusions with diminished amplitude and frequency of action potentials from the masseter of the contralateral side. He stated that the contralateral muscles function to stabilize the mandible, while the ipsilateral musculature is in a position to exert maximal tension. Pruzansky found that where he obtained no change in the muscular pattern in chewing from one side to the other, the occlusion was characterized by a deep cuspid overbite rendering the patient incapable of performing lateral movements. In these subjects, the chewing pattern was characterized by "chopping" movements which posed the question, does he possess a less efficient mechanism? In the masticatory stroke, maximal activity of the temporal and masseter muscles, he pointed out, is not achieved until the jaws approach centric occlusion. The peak of this force has added dimension in the form of duration while a "chopping" stroke is short and ballistic and therefore, not as efficient in trituration.

Geltzer (1953) showed that by maintaining variables constant, data collected from one time to the next could be reproduced, thus proving the value of longitudinal electromyographic studies. He also stressed the importance of posture maintenance in longitudinal studies as did Greenfield and Wyke (1956).

MacDougall and Andrew (1953) in studying the action of the various components of the temporal muscle found: (1) in the occlusion of the incisor teeth, there was little activity in the temporal, most of the activity being from the masseter, (2) protraction showed most activity from the masseter and retraction from the posterior temporal fibers, (3) little activity beyond that shown at rest on opening movement, however, maximal opening resulted in considerable activity over all these muscles. This last point is most important in that the activity of the temporal and masseter muscles during opening, which is thought to be a restraining action against dislocation of the temporomandibular joint, must be taken into consideration when interpreting integrated myograms using amplitude as a measure of muscle activity. For example, in the studies done at Northwestern by Perry and Harris (1954) and Perry (1955) an integrated graph of the myogram was used to determine which muscles initiated the chewing stroke in different types of malocclusions. It is possible that some of the activity noted in certain muscles that they thought were initiating the chewing stroke were actually amplitudes recorded during the opening movement of the mandible. This may also be supported by the fact that some of their findings are in disagreement with those found by a majority of the investigators working in this area.

Perry and Harris (1954) in comparing normal occlusions with Class II Division I malocclusions used a transformed myogram. The transformed myogram was accomplished by ruling off five millimeter intervals on the tracings which at their paper speed made these intervals equal in time to fifty milliseconds. The amplitude of each spike potential within the fifty millisecond interval was measured, totaled, and plotted on a graph which used time in milliseconds and amplitude in microvolts as the co-ordinates. The activity of both temporal muscles and both masseter muscles were plotted on the same graph, using a different color for each muscle. In this manner, they attempted to show the presence or absence of synchronism in activity between muscle groups. They found in normal occlusions as maximum activity was reached, there was sychrony of temporals and masseters of both sides, the temporals showing activity before the masseters. There was more harmony of action potential discharge when chewing on the preferred side. They found in the malocclusion group that the temporal and masseter muscles on both sides reached maximal activity asynchronously. They also stated that the masseter muscles frequently were the first to manifest electrical activity and that there was less harmony and smoothness of action potential discharge on both sides but that there was less disharmony on the preferred side. It must borne in mind, however, that these interpretations were made not from the myogram itself but from a graph using only amplitude as a basis for interpretation.

Perry (1955) reporting on a study of the temporal and masseter muscles in Class II Division 1 malocclusions and excellent occlusions using the transformed myogram concluded that the temporal muscle of the functional side manifested activity before the opposite temporal or masseter in normal occlusions. This is in disagreement with the work of Pruzansky (1952) and Jarabak (1954). Both Pruzansky and Jarabak found synchronous discharge in the two temporals and the two masseters in normal occlusions. Perry also noted that there was synergy of all the muscles during function showing an apparent harmony and correlation of muscle activity when there are normal inclined plane and cusp relations. In the malocclusion group, he found no single muscle unit which appeared to initiate the chewing cycle consistently, and very little synergy of contracting units. Perry said: "In all patients (malocclusion) there was an inconsistent multiplicity of amplitude peaks and a "searching pattern" in the contraction units." He also states that the preferred side showed greater synchrony and harmony in both normal and malocclusion groups.

Jarabak (1954) in a study of the adaptability of temporal and masseter muscles of a cleft palate and harelip subject (that was surgically repaired at an early age, resulting in an excessive interocclusal space of seventeen millimeters), showed by using a chewing medium that offered variable resistance and an orthodontic splint that increased the size of the occlusal table and reduced the interocclusal space to three millimeters, that in this patient synchronous firing of the temporal and masseter muscles was lost both ipsilaterally and contralaterally. Reduction of the excessive interocclusal space restored synchrony to the masseter and temporal muscles of both sides and brought back into action the masseter of the contralateral side that had previously been electromyographically silent. He described the neuroanatomical structures and neuromuscular mechanism governing mandibular movements in detail and pointed out how there is a distinct relationship electromyographically between occlusion of the teeth and functional muscular patterns taken from the temporal and masseter muscles during mastication. He found that muscular patterns are altered by hardness, size, resistance of the chewing medium, occlusion of the teeth and interocclusal space. By comparing subjects having a malocclusion and a normal occlusion he concluded that the function of the temporal muscles in normal occlusion is to elevate the mandible and that of the masseters is to give power to the masticatory stroke; in the subject with the malocclusion the temporal provided both functions, therefore, although there may be a division of labor between the two muscles in normal occlusion, the temporal muscle is capable of doing all the work. Jarabak stated: "It may be logically assumed that one cannot ascribe a true function to any given muscle for any given time. The function of the muscles is generally predetermined by the status-quo of the body in space." Jarabak's findings were based on a thorough interpretation of the myograms taking into consideration amplitude, duration, form, bursts of activity and areas of inhibition. It is interesting to note that although his findings do not agree with some of those of Harris and Perry (1954) and Perry (1955), his findings corrobrate those of most of the other investigators, Moyers (1949), Pruzansky (1952) and MacDougall and Andrew (1953).

Zwemer (1955) in working with cleft palate patients with insufficient maxillary development compared the response of the temporal and masseter muscles in carrying the mandible from rest to occlusal contact in these patients, with normal occlusion patients. He showed that the temporals are primarily responsible for the closing movement of the mandible in patients with normal occlusion and normal inter-occlusal space, but in cases with excessive interocclusal space, there was an increase in action potentials from the masseters and temporals of both sides which returned to normal when restoration was made to normal interocclusal space with a prosthesis. It is important to note that the gravimetric technique used by this investigator in interpreting his data is a possible source for the incorporation of great error.

Jarabak (1956) showed electromyographically that subjects having temporomandibular joint dysfunction symptoms showed a spasticity of the posterior temporal fibers during rest position immediately after talking or chewing, and that this spasticity could be eliminated after function when occlusal interferences were eliminated. He also showed, in subjects where occlusal interferences were eliminated by the use of a splint, that spasticity returned when the splint was removed. Jarabak concluded on the basis of these findings that the behavior of skeletal muscle is an index to the state of the motor center (lower motor neuron) and that temporal muscle spasms occur simultaneously with functional disturbances of the temporomandibular joint and may have their etiology in occlusal interferences of the teeth. He attributed deeply seated muscle pain to physiochemical changes in the spastic muscle.

Karau (1956) in working with orthodontically treated occlusions and untreated malocclusions of the teeth, obtaining readings bilaterally, of the masseters and middle temporals, found that during deglutition and mastication untreated subjects showed more temporal than masseter activity with the situation being the reverse in treated subjects. He also found that in both groups one temporal consistently showed greater activity than the other regardless of which side was the functional side. His findings indicated that the temporal was best suited for movement and positioning of the mandible, while the masseter was best fitted for function as a power muscle (Jarabak, 1954). Karau concluded that harmony in occlusal relations of the teeth is the primary determinate of excellent muscle function rather than the sagittal relation of mandible to maxilla.

Greenfield and Wyke (1956) tried to determine if a pattern of muscular co-ordination for various movements of the mandible in the normal individual could be identified and compared with such patterns found in cases of malocclusion. They found that although an underlying electromyographic pattern of reflex muscular co-ordination could be demonstrated, they could not make absolute comparisons between cases due to variations within groups. This is in direct contrast to most findings of earlier investigators. They stressed the importance of head position and electrode placement in longitudinal studies. They also concluded that bilateral recordings and recordings of homologous muscles working together were of more significance than unilateral recordings and that minor variations in muscular patterns exist between individuals with normal occlusions. They stated: "Any one movement involves a fundamental pattern of activity which is consistent from time to time in any one individual, and is similar from individual to individual."

Latif (1957) using bipolar surface electrodes, studied the temporal muscle electromyographically in normal occlusions. He concluded that his surface electrodes compared favorably with the needle electrode. Some of his findings were in disagreement with those of Moyers (1950), however, he was able to obtain Moyers results using the same method as Moyers. He attributed the difference in findings to the difference in electrodes and the fact that placing the reference electrode on the ear lobe as Moyers had done introduced extraneous electrical activity into the recordings because the reference electrode was "too far away". His findings that the temporal maintains posture, the posterior fibers being the more active, thus differed from Moyers' conclusion that in normal occlusion equal activity exists in both anterior and posterior temporal fibers. His further findings were that during maximal opening of the mouth, the temporal acts as an antagonist and prevents the temporomandibular joint from being dislocated, the temporal is a very active elevator of the mandible and does not play any part in protraction, and also retracts the protruded jaw, thus supporting the findings of Jarabak (1954) and MacDougall and Andrew (1953).

Blenker (1957) in an electromyographical comparison of Class III malocclusions with normal occlusions showed, by studying the suprahyoids and the masseters, that there was co-ordination of muscular activity and also a definite lack of synchrony found in both groups. This indicates that improper relation of maxilla to mandible does not necessarily affect muscular activity adversely when harmonious functional occlusion is present. Blenker said: "Disharmony of intermaxillary tooth contact during function, rather than the adverse relationship of skeletal parts of the facial complex per se, may be the cause of poor muscle pattern found in some Class III subjects."

Greenfield and Timms (1957) in doing electromyographic studies on orthodontic patients before and after treatment, stressed the importance of taking bilateral recordings. Their studies indicated that lateral deviations could be shown by comparing the time of onset of activity of the two sets of posterior temporal fibers, and that the antero-posterior positions of the mandible by the time of onset of activity of the masseter (superficial and deep fibers). They drew no conclusions, however, as to the adaptability of the temporal and masseter muscles after orthodontic treatment.

Jarabak (1957) in studying the effect of excessive and insufficient inter-occlusal space on temporomandibular musculature, found tension in the mandibular elevators in cases with insufficient inter-occlusal space, and spontaneous hyperactivity in those with excessive inter-occlusal space. He concluded that electromyography could be used clinically to a great extent in establishing a correct vertical dimension.

Hickey, Woelfel and Rinear (1957) studied the influence of overlapping electrical fields on the interpretation of electromyograms. They found that: (1) electrical activity thought to be originating from certain muscles or areas may actually be overlapping electrical fields from other muscles, (2) electrical activity from the mid-portion of the masseter during uncontrolled opening or lateral excursions, is thought to arise from the external pterygoid, (3) reference points, such as ear lobes, are not necessarily inactive, (4) overlapping electrical fields may cause incorrect interpretation of the myograms leading to erroneous conclusions, (5) overlapping fields of electrical activity should be recognized and considered in the interpretation of the electromyograms.

Hickey, Stacy and Rinear (1957) using monopolar surface electrodes and Moyers' method of electrode placement, studied electromyographically the mandibular muscles during basic jaw movements. They used a transformed myogram in interpreting their findings. Their conclusions were in general agreement with those of other investigators concerning muscle action during various jaw movements. They also state that electromyography does not indicate movement but only shows an increase or decrease of electrical activity of a part and makes no distinction between isometric or isotonic contraction.

Poritt (1957) studied the effect of occlusal interferences, which were placed by means of inlays, electromyographically on the temporal and masseter muscles. He concluded that: (1) a single restoration with occlusal interference is enough to alter the contraction pattern from bilateral symmetry and balance to an assymmetrical pattern, removal of interferences restores the original pattern, (2) occlusal interferences can inhibit muscle activity during mandibular movements, muscles adopt an occlusal position for efficient movement shortly after interferences are placed, (3) the location of the area of interference on the tooth is more important than the location of the tooth in the mouth as regards to the effect on the muscular contraction pattern. He also found the temporal to be more sensitive than the masseter in response to occlusal interference. This seems to be in general agreement with what has been found by most earlier investigators.

Sutton (1960) compared electrodes for electromyographic procedures to determine the effects different electrodes would have on electromyographic records. He found that needle electrodes and surface electrodes did show comparable voltages and that similar electrodes recorded differently depending on their position in or on the muscle.

Ahlgren (1960) in an electromyographic investigation of the response of mandibular musculature to activator therapy found that reflex activity can be changed to a new and more faborable contraction pattern, the new pattern being reinforced and maintained by afferent signals from the periodontal membrane of the teeth, whose intercuspation has been improved by the treatment.

Bjorg (1960) also did work on the effect of activator therapy electromyographically on the temporal and masseter muscles. He found that in distocclusion cases after insertion of the appliances, that increased activity was noted in the posterior temporal fibers. No activity being noted in the masseters in cases of retruded mandible. Bite pressure on the activators changed the balance of activity to the anterior temporal fibers and the masseter fibers, which substantiates Ahlgren's findings. In the use of the fixed appliance, the balance of muscular activity was not changed.

Liebman and Cosenza (1960) studying the etiology of malocclusions electromyographically, attempted to determine the total patterns of muscle activity and how they vary from individual to individual with different types of malocclusion. They felt that since the rationale for electromyographic studies has been that malocclusions alter the proprioceptive inflow to the central nervous system from the periodontal proprioceptors and that this in turn altered the motor output to the mandibular musculature, there should be a typical electromyographic pattern for normal occlusions and for the different types of malocclusions.

They were unable to distinguish, electromyographically, individuals having normal occlusions from those having malocclusions. They found no specific patterns of muscle function in individuals with normal occlusions or malocclusions, and no correlation between type of occlusion and degree of electrical activity during the resting state of the muscles. They did find that electrode placement influences the amplitude of the myogram.

It is interesting to note that although their methods were similar to those employed by other investigators, their findings were in direct contrast to almost all of the work done in this field.

Widen (1960) beginning an electromyographic study of the masseter and temporal muscles before, during, and after orthodontic treatment found that one half of the experimental subjects showed evidence of adaptation, that is, no marked influence in the behavior of temporal and masseter muscles twenty-four hours after the placement of separating wires between the teeth. He also found an increase in the duration of the chewing stroke, and a greater variability in the onset of activity of the masseter and temporal muscles. These changes were attributed to a change in periodontal sensory reception. Asahino (1960) following Widen's work, compared pretreatment electromyograms of the same patients with those taken seven days after the placement of separating wires between the teeth. He found that any changes that did occur earlier in the behavior of the temporal and masseter muscles as a result of the separating wires, had disapprearared by the seventh day in twelve out of sixteen subjects. He attributed the disappearance of the changes, in part, to the adaptation of the neuromuscular mechanism.

Shanahan (1960) in comparing the pretreatment myograms of the same patient with those obtained one week after the placement of the first arch wires showed that some of the subject who seemed to adapt to the placement of separating wires again showed an altered pattern of muscular behavior. Those subjects showing a change in muscular behavior presented an increase in the duration of the chewing stroke and an increased number of bursts of activity in the chewing stroke, The temporal muscle, especially the posterior fibers, showed a more active and the masseter a less active role in initiating the activity of the chewing stroke. Changes in the muscular behavior were again attributed to altered periodontal proprioception.

Zylinski (1961) in the fourth part of the same longitudinal study compared the myograms of the original malocclusion with those taken six to eight weeks after the placement of the first archwires. He showed pain to be more instrumental than proprioception in obvious changes in the motor behavior of the temporal and masseter muscles. The division of labor between these muscles was least when the mandibular teeth were uprighted, the temporal muscle initiaing the forceful chewing stroke more often than the masseter muscle during anchorage preparation as compared with before treatment recordings. As treatment proceeded the frequency of initial activity onset by the temporal muscle increased and that of the masseter decreased.

Fleming (1961) in the fifth part of the same study compared myograms taken twelve to sixteen weeks after the placement of the first arch wires at the end of anchorage preparation with those taken before treatment. In re-evaluating the data in previous experiments, Fleming found the greatest amount of inhibition to be in Experiment III, one week after placement of separating wires. This apparent contradiction to Asahino's findings were brought forth by counting the number of bursts of activity in the chewing cycle which had not been done previously. This showed the number of times inhibition had taken place and proved to be greater than at any other time in this study. Fleming found a change in the division of labor between the masseter and temporal muscles, the masseter contributing less and less from before treatment through to the completion of anchorage preparation, the duration of the chewing stroke also increased. These results were attributed to painful experiences during mastication. Fleming concluded that: ". . .the number of bursts in a chewing stroke is a reasonably good indicator of how many times inhibition has taken place in the muscle being studied."

Grossman, Greenfield and Timms (1961) state that electromyographic examination of the masticatory muscles offer an exact and reliable scientific tool for assessing maxillomandibular relationship. Furthermore, they said that there is a basic electromyographical pattern of reflex co-ordination for the individual bite usually seen in normal occlusions and sometimes in abnormal occlusions. They classified these basic patterns into three main groups and two minor groups. The groups are as follows:

1. The individual bite shows considerable activity of all muscles under consideration with the deep masseter showing less activity than the superficial.
2. In incisor and protrusive bite the posterior temporal activity drops. Varying activity is seen in the posterior temporal depending on the force of the bite.
3. Biting into a forced retrusive shows high activity of posterior temporal and lowered activity of the anterior temporal. But the greatest change is seen in a drop of activity in the superficial masseter. The deep masseter usually shows greater than, or at least equal activity to, the superficial masseter.

4. In protrusive without biting, the deep masseter shows the greatest activity.

5. In retrusive without biting, the posterior temporal shows the greatest activity.

They are of the opinion that eccentric bites show myograms that differ on both sides. They also state that clinical examination usually reveals the reason for slight electromyographical variations in "so-called normal occlusions". In those cases, in which the myogram was not normal after treatment, this was attributed to the muscles not adapting or the mandible being held distally by a changed position of the teeth. It is of interest that Greenfield, who with Wyke (1956) found that he could not identify patterns of muscular behavior in normal occlusions and compare these patterns with those found in cases of malocclusion, is now able to identify and compare muscular behavior patterns in normal occlusions and malocclusion. These are the only investigators who have been able to show that they could separate malocclusions on the basis of the muscular electromyographic pattern so easily.

Ralston (1961) in discussing the possibility of quantitating the data from electromyographic investigations in dentistry felt that because of the technical difficulties involved, he did not hold very high hopes that a valid method of quantitating the data would be found in the near future.

It is hoped that certain things have been brought to the foreground in this review of the literature that should be taken into consideration in any future investigations in this field.

1. There exists at present no method of standardization in the type of electrodes used, their placement and the placement of the reference electrodes.
2. There is no standardization in the muscles and/or muscle fractions being studied.
3. No two investigators interpreted the data in the same manner - again a need for standardization in this area.
4. In all of the studies performed, there was no uniformity in the selection of subjects, number of subjects used, in the jaw movements performed and in the chewing medium used.

Apparent contradictions in the literature could possibly be attributed to the above factors. Also agreement, or what may seem on the surface to be agreement in findings, may not necessarily be the case. It has been the purpose of this review to try to point up these facts.

It is also felt that most of the investigators, since they only used one method of interpretation and did not apply statistical discipline to their findings, did not get the most out of their data.

CHAPTER II

METHODS AND MATERIALS

A. Selection of Subjects

Sixteen patients between ten and fourteen years of age were selected for this longitudinal study, by the first investigators, from the orthodontic clinic of the Loyola University School of Dentistry. These patients presented with Class I and Class II (Angle) malocclusions and were treated with light, resilient wires and light elastic forces. At the time records were taken for this part of the study, these patients were between twelve and sixteen years of age.

B. Muslces Studied

The muscles selected for study were the posterior and middle fibers of the right and left temporal muscles and the right and left masseter muscles. These muscles were chosen because of their importance in masticatory function and accessability for the placement of surface electrodes. The middle temporal fibers act as elevators of the mandible. The posterior temporal fibers are concerned with lateral and posterior movements of the mandible. The masseter muscles provide power in elevating the mandible. The muscles of both sides were recorded simultaneously during chewing on both right and left sides.

C. Electromyographic Equipment

The electromyographic equipment (Figure 1) consisted of a G.M.E. (Gilson Medical Electronic) eight channel polygraph modified to record electromyographic voltages, with one channel altered for recording electrical impulses from a bone conduction microphone, a built-in microvolt calibrator, and a Faraday cage, within which an electrode terminal board was mounted. Patients were seated in the Faraday cage while records were taken. The Faraday cage reduced extraneous electrical activity to an isoelectric point. The amplifiers and filters were set to give the greatest fidelity of transmission. The pen deflection was calibrated before and after each experiment to make sure that the system was operating uniformly throughout the full range of deflections that might be expected. The pen deflection (sensitivity) was 23 mm., or 11 1/2 mm. on either side of the base line, for 500 microvolts peak. The paper speed was 6 cm. per second which would make the distance between the vertical lines on the tracing paper equal to 0.1 second in time.

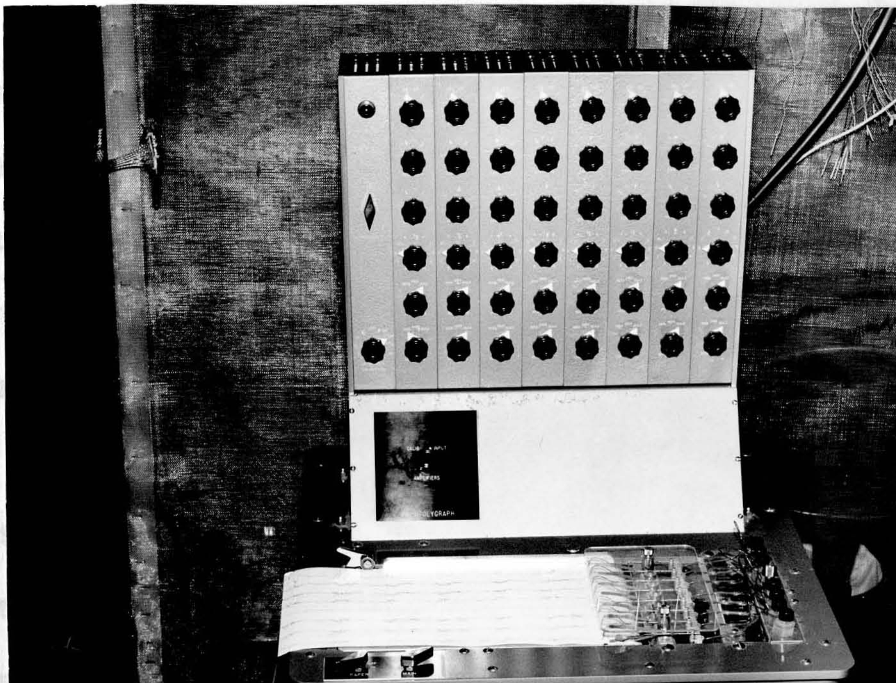


FIGURE 1

G.M.E. POLYGRAPH

D. Sound Equipment and Recordings

The components of the sound system (Figure 2 and Figure 2A) were a bone conduction microphone (Zenith Hi-Lo, Regent Type), a matching transformer (Shure Model A86A), a preamplifier (Heathkit WA-P2) and necessary power supply, a tape recorder (Wollensak Stereo Model T-1515), and one channel of the polygraph.

The bone conduction microphone (Figure 3) was placed on the subject's head and held in position by a spring-type headband. The microphone was connected through the matching transformer to the preamplifier. The output from the preamplifier was sent into the tape recorder and the polygraph. Tape recordings were made at seven and one-half inches per second with a volume level of five, tone control at "treble" and the monitor switch at "on" position. The chewing and tapping exercises were audibly monitored through the tape recorder as they were recorded to insure proper performance of the exercises. The output from the preamplifer entered a channel of the polygraph and was converted into "sound tracings" by the polygraph. These "sound tracings" called "sonograms", were simultaneously recorded with the myograms. The term, "sonograms", used here has been described by

FIGURE 2

SOUND EQUIPMENT AND PATIENT SEATED IN FARADAY CAGE

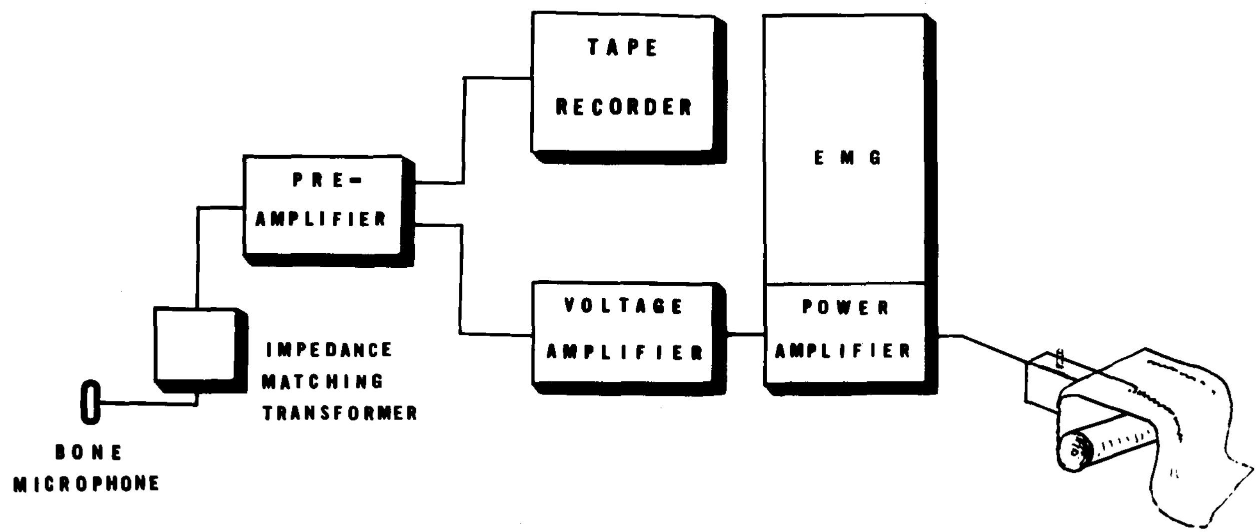


FIGURE 2A

SOUND SYSTEM

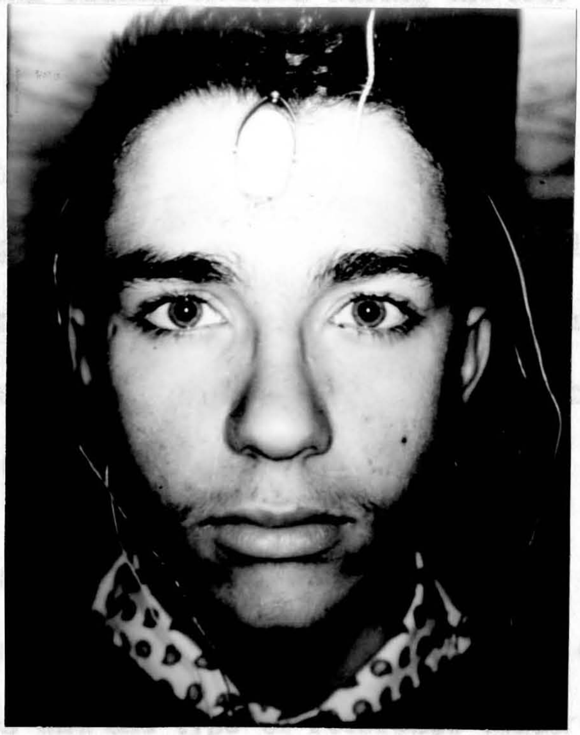


FIGURE 3

SUBJECT WITH BONE CONDUCTION MICROPHONE IN PLACE

B. Widen (1960) in the first part of this study. The sonograms consisted of a base line and deflections from the base line (spikes) of varying amplitudes, frequencies and durations, which corresponded with the tapping and chewing sounds emitted during the test exercises. (See Figure 13.)

E. Chewing Medium

The chewing medium used was Vick's cough drops. Vick's drops were selected because of their uniform size and hardness. Chewing this material yielded sounds easily detected by a bone conduction microphone placed on the forehead.

F. Electrodes and Electrode Placement

Three types of electrodes were used (Figure 4), two types of surface electrodes and one type of reference electrodes. The reference electrodes consisted of ear clips which were fastened to the subject's ear lobes. One type of surface electrode used was a monopolar disk, silver surface electrode 5/16 inch in diameter, and the other a Welsh Self-Retaining Electrocardiographic Electrode. The latter type of surface electrode consisted of a hemispherical, nickel silver cup, 15 mm.

FIGURE 4

ELECTRODE PLACEMENT

in diameter, attached to a binding post and to a rubber bulb in such a manner that when the bulb was compressed, the cup applied to the prepared skin, and the bulb released the cup would adhere comfortably. The Welsh surface electrode was used on the masseter muscle because of its ease of application, but not on the temporal muscle because of difficulties in keeping this type of electrode in place over the temporal region where the hair had been clipped.

Surface electrodes were used because the temporal and masseter muscles lie close to the skin on the side of the head. The absence of underlying superficial or adjacent muscle tissue makes the use of this type of electrode more practical for studying these muscles. The surface electrodes were placed bilaterally on the bellies of the posterior and middle temporal fibers and on the masseter muscles midway between their origins and insertions. To facilitate correct electrode placement the patient was instructed to clench his teeth and then relax, enabling the operator to palpate and select representative areas of the muscles studied. When necessary, the hair was trimmed, exposing an area approximately one-half inch in diameter. The selected areas were cleansed with soap and water, rubbed with acetone and then with electrode jelly. Skin resistance was thus reduced to 5,000 ohms or less which facilitated greater pick up of low amplitude electrical potentials from the muscles. The skin resistance was checked with an ohmmeter after the placement of all the electrodes. The reference electrodes were clipped to the ear lobes after similarly preparing the skin surface. The surface electrodes on the temporal muscle were held in place by colloidin, after the colloidin had set, securing the surface electrode to the skin, a blunted 18 gauge needle and Luer-Lok syringe were used to inject electrode jelly, through a hole in the disk electrodes, so that the space between the electrode and the skin was filled with a conducting medium.

G. Experimental Procedure

The subject was seated in a Faraday cage, the electrodes connected to the terminal board, and the bone conduction microphone placed on his forehead (see Figure 3). A printed list of instructions was given to him and the procedure explained. The subject was told to recite each item on the list, which was recorded on tape, and then to perform the required exercises. The exercises were: (1) "rest", (2) tap teeth together in centric occlusion, (3) chew a cough drop on the right side,

(4) chew a cough drop on the left side. Resting was enhanced by instructing the subject to relax, close his eyes, allow his arms to lie passively in his lap, his feet flat on the floor, and the head positioned with Frankfort Horizontal parallel to the floor. When the polygraph showed minimum movement, this indicated muscular rest, which was recorded. Tapping was performed ten times, "slowly and hard". At the beginning of the chewing exercises the subject placed the cough drop between the teeth on the designated side and was told to "chew slowly and hard ten times". Duplicate exercises were performed to minimize the experimental error. Tape recordings of all recitations and exercises were made along with the myograms and sonograms.

Recordings were taken in Experiment VII, in the same manner as in Experiment I, the same instructions being given and complete records taken as before, with the exception, that since a different machine was being used it was possible to record from all muscles of both sides simultaneously.

H. Orthodontic Procedure

Each subject's full complement of teeth were banded using angulated brackets on each band. The posterior brackets (those of the bicuspids and molars) were angulated from the horizontal to give the teeth a distal-tip-back when a straight wire was placed in the bracket slots. The brackets of the mandibular posterior teeth were angulated eight degrees while those of the maxillary posterior teeth were angulated five degrees. The maxillary and mandibular incisor brackets were angulated two degrees from the horizontal to give the incisor teeth a slight mesial convergance toward the mid-line for artistic positioning. Those of the maxillary canines were not angulated, whereas the mandibular canines had an angulation from the horizontal of seven degrees to tip the mandibular canine mesially. In addition all brackets were torque slotted so that when a rectangular straight archwire was placed in the bracket slots the teeth would assume their correct axial inclinations in a bucco or labio-lingual direction. At the time of this experiment the distal tipping and uprighting of the posterior teeth, had already been accomplished. This experiment dealt with the final stages of treatment.

The final stages of orthodontic treatment consisted of consolidation of spaces, correction of molar relation, leveling of the occlusal plane, the lingual tipping of the roots of the maxillary incisor teeth if necessary, final artistic positioning of the teeth and the "seating" of the occlusion.

The archwires used in the treatment of all the subjects were made of round .016 inch diameter or square .016 x .016 inch or rectangular .016 x .022 inch Elgiloy-Semi-Spring wire which is light and resilient in nature. The main working arches were of .016 inch round wire while the square and rectangular wires were used mainly for torquing archwires (archwires desgined to tip to roots of the maxillary incisor teeth lingually) and ideal archwires for acquiring final arch form and artistic positioning of the teeth. Prior to their insertion all archwires were fashioned individually for each subject, and then tempered to spring hardness. During the final stages of treatment several configurations of archwires were used.

A. The Consolidation Archwire

This archwire was used in the upper and lower dental arches. It was fashioned to the shape of an ideal arch, and individualized for arch width and form for each subject. It employs bent-in hooks located as close to the distal surfaces of the brackets of the lateral incisors as possible (Figure 5).

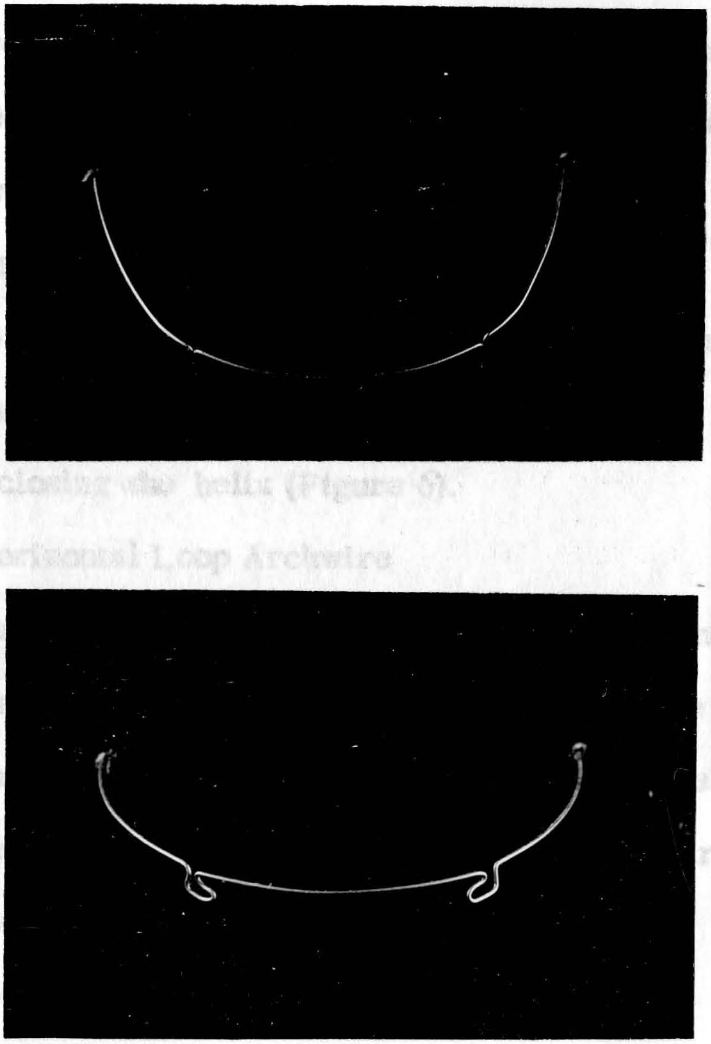


FIGURE 5

CONSOLIDATION ARCHWIRE

B. The Vertical Contraction Loop Archwire

This archwire was used in the upper and lower dental arches. It is shaped to ideal arch form and individualized for the subject and employs two closed, vertical, helical loop springs, one on each side of the arch, and is activated by pulling the distal section of the wire through the molar tubes and stopping them there by placing a bend in the wire. In the closed vertical loop spring the legs are crossed so that the loop is activated by closing the helix (Figure 6).

C. The Horizontal Loop Archwire

This archwire was used in the upper and lower dental arches. It employs horizontal helical loop springs to bring about the desired movement of teeth in the vertical plane. It is fashioned to the shape of an ideal arch as nearly as possible and individualized for arch width and form for each subject (Figure 7).

D. The Torquing Archwire

The torquing archwire was used in the upper dental arch only. It was fashioned from rectangular resilient wire and employed a helix on either side of the maxillary lateral incisor to store the torque force (a force created by the untwisting of a wire which tends to tip the roots

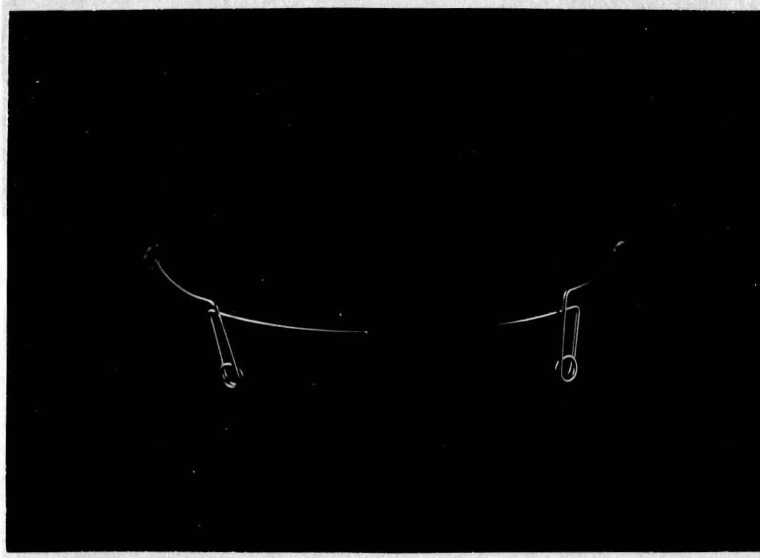


FIGURE 6

VERTICAL CONTRACTION LOOP ARCHWIRE

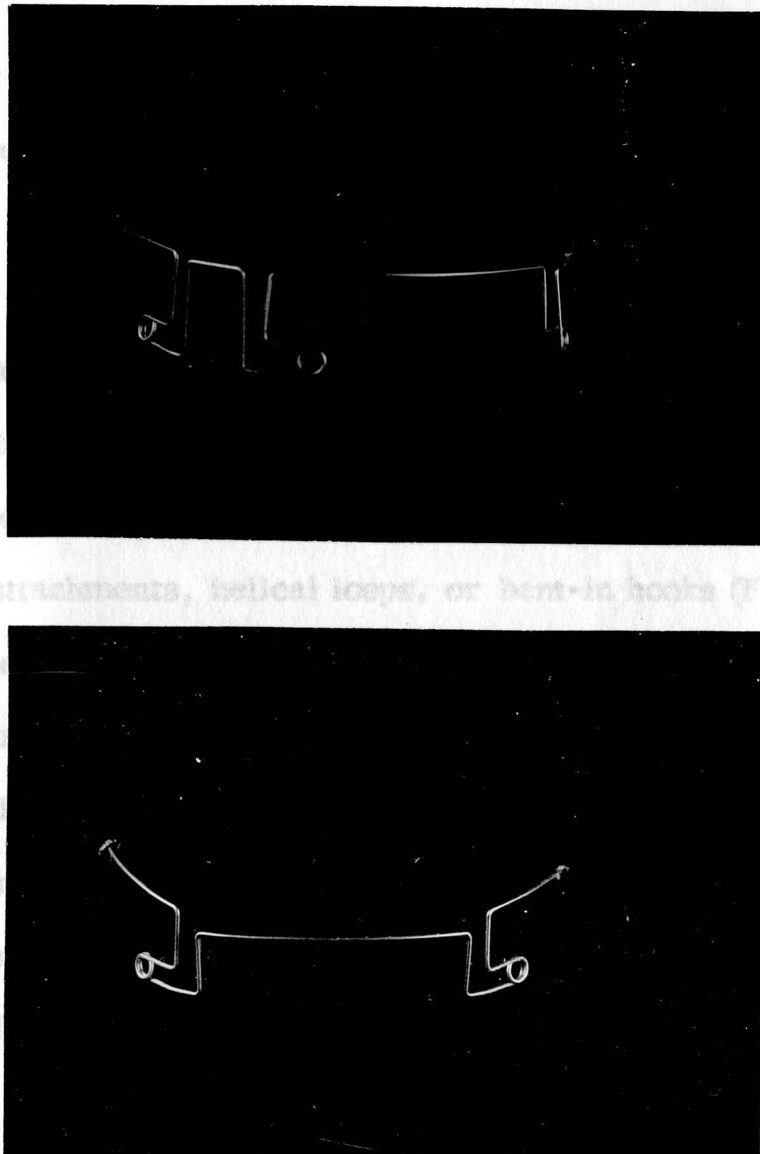


FIGURE 7

HORIZONTAL LOOP ARCHWIRE

of the upper anterior teeth in a lingual direction). The distal ends of this wire are curved buccolingually to conform with arch form and are also curved gingivally to create a greater range of deflection and a gentle force (Figure 8).

E. The Straight (horizontal) Archwire (.016 round)

This archwire was used in upper and lower arches. It was individualized for arch width and form for each subject. These archwires carried no attachments, helical loops, or bent-in hooks (Figure 9).

F. The Straight (horizontal) Archwire (.016) with Attachments

This archwire was used mainly in the lower dental arch. There were only slight bends incorporated in the posterior segments to conform to general arch form. The attachments consisted of two sections of .010 closed coil spring placed on the wire to advance two sliding hooks. The distal end of the coils contacted the brackets of the first premolar teeth or the first molar teeth and the hooks were advanced by the coils to a position mesial to the canine teeth. The bands on the canine teeth were removed in order to allow the springs and hooks to be advanced, without interference, to a point mesial to the canine teeth (Figure 10).

G. The Ideal Rectangular Archwire

This archwire was used in both upper and lower arches and was

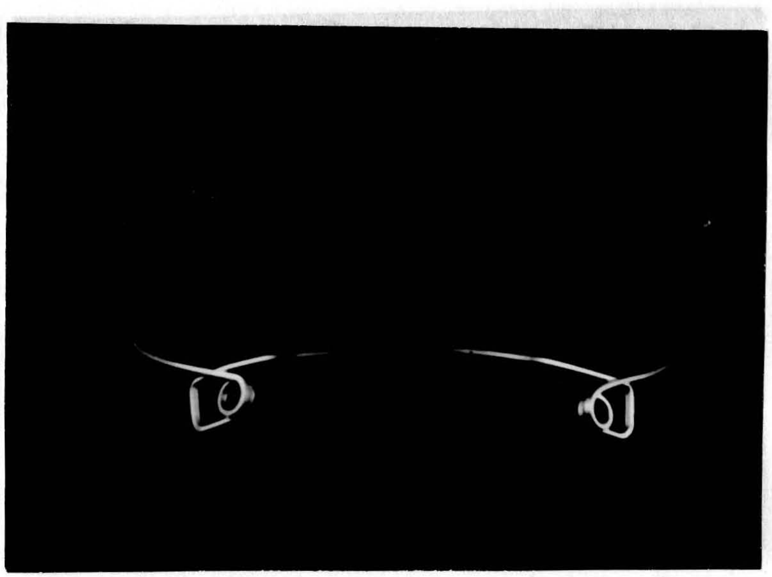


FIGURE 8

TORQUING ARCHWIRE

FIGURE 9

STRAIGHT HORIZONTAL ARCHWIRE

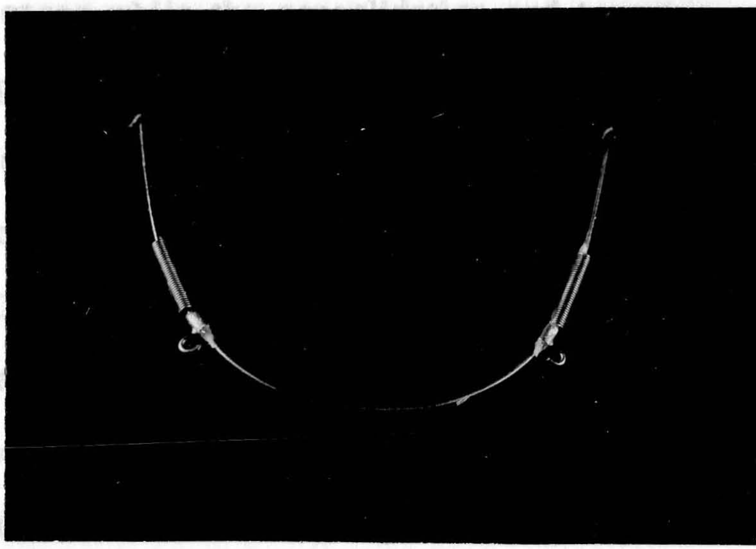


FIGURE 10

STRAIGHT HORIZONTAL ARCHWIRE WITH ATTACHMENTS fashioned individually for each subject. The wire conformed to ideal arch form and in addition contained first order or offset bends for the canines and molars and, in the maxillary archwire, for the lateral incisors. These wires carried no attachments (Figure 11).

In some cases while the consolidation and torquing archwires were being used, high-pull headgear was used to create an oblique force in a distal and upward direction against the maxillary anterior teeth. High-pull headgear consists of two headgear hooks, two (or more) elastics and cloth belting. The two headgear hooks are attached to the maxillary archwire between the maxillary lateral and central incisors and are placed under tension by means of "X" type Ortho-Spec elastics. These elastics are stretched from the headgear hooks to hooks riveted to the belting, which fits over the head. Thus, an extraoral force for the movement of teeth is applied. The headgear force applied in this technique is between nine and twelve ounces.

The elastics used in conjunction with the archwires just described were: light 1/4 inch latex elastics which exerted an average pull to two ounces when stretched a distance of one and one-fourth inches. This is the average distance used in the treatment of the malocclusions.

FIGURE 11

IDEAL RECTANGULAR ARCHWIRE

Also heavy 1/4 inch latex elastics were used which exerted an average pull of four ounces when stretched a distance of one and one-fourth inches.

The latex bands were worn bilaterally in the following ways:

A light intermaxillary elastic worn from a hook located on the lingual surface of the band on the mandibular first molar to the bent-in hook or sliding hook or helix of a torquing arch located mesial to the canine tooth.

A light intermaxillary elastic worn from the end of the archwire on the buccal surface of the mandibular first molar to the bent-in hook located mesial to the upper canine brackets.

A light intramaxillary elastic worn from the end of the archwire distal to the molar tube on the buccal surface of the mandibular first molar to the bent-in hook located mesial to the mandibular canine bracket or to a contraction loop in the mandibular arch.

A heavy triangular elastic worn buccally from the lower to the upper arch, the triangle had its base on the upper arch and its apex on the lower arch. The elastic worn in this fashion was attached from the end of the upper archwire on the first molar distal to the buccal tube to a hook made from the ligature tie on the upper second premolar tooth, then down to a similar ligature tie on the lower second premolar tooth.

Some of the patients already were on retention at the time this part of the experiment was done and were using rubber finishing appliances (see Figure 12) which were made of vulcanized rubber that was resilient in nature and constructed to gently move the teeth, through functional exercising, into their final, ideal positions. After the occlusion was "seated" these appliances were kept and used as retainers.

I. Utilization of Sound Data to Interpret Electromyograms

The data consisted of myograms, sonograms, and tape recordings of the temporal and masseter muscles taken during tapping, chewing, and at rest. The myograms and sonograms taken at rest permitted an evaluation of the base line or minimum activity in the muscle and sound channels. Myograms compared with the sonograms taken during the tapping exercises, showed a correlation between tapping sounds and muscle activity. The sonograms of tapping were simple, consisting of single spikes, while those of chewing were more complex (Figure 13 and Figure 14).

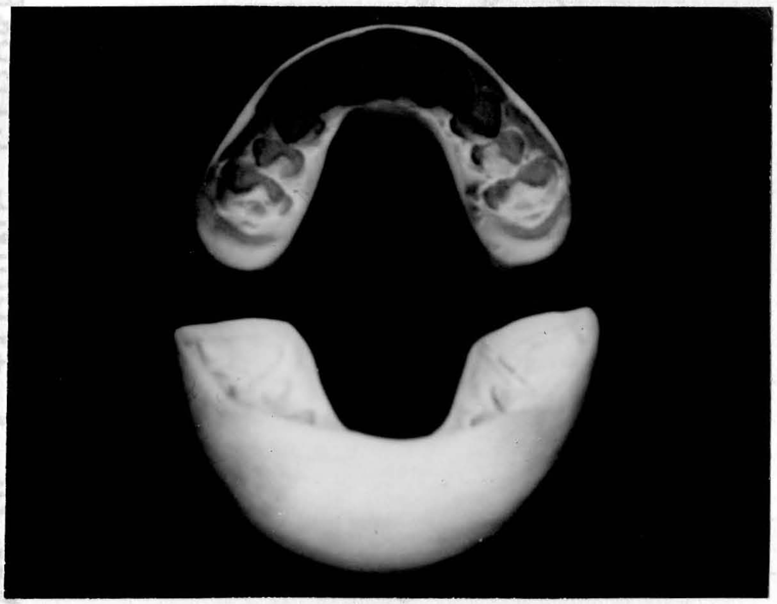


FIGURE 12

RUBBER FINISHING APPLIANCE

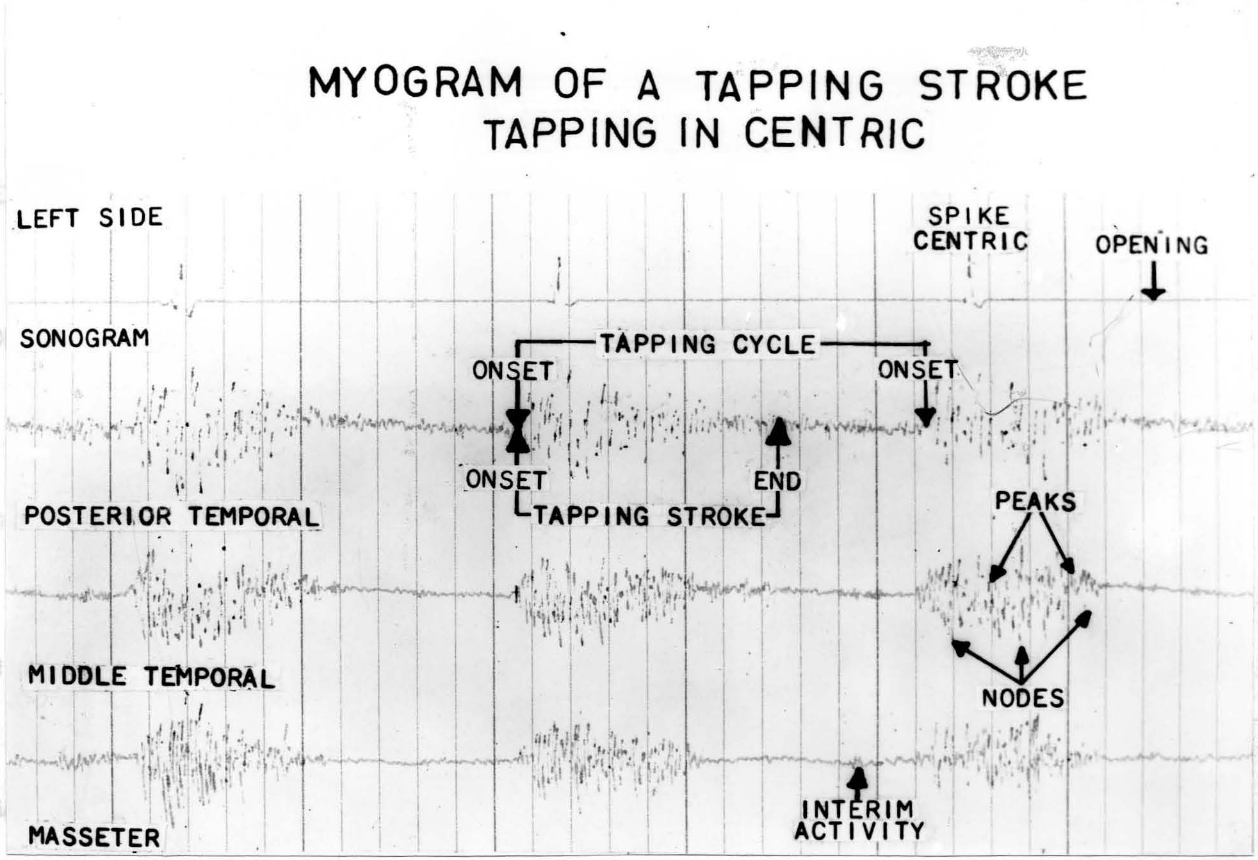


FIGURE 13

MYOGRAM OF A TAPPING STROKE

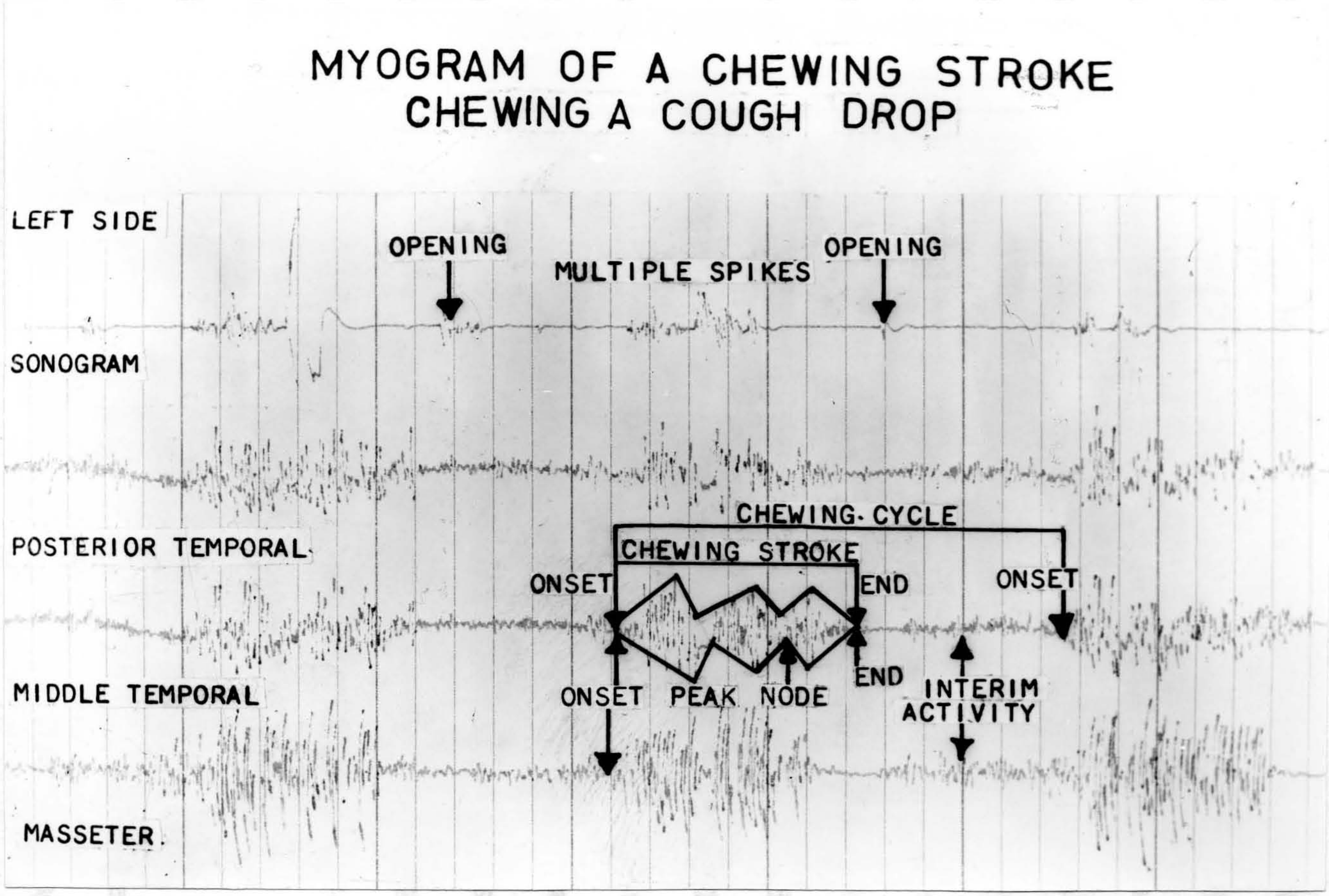


FIGURE 14

MYOGRAM OF A CHEWING STROKE

The sound of the teeth meeting in centric occlusion produced a sharply defined mono or polyphasic sonogram. By noting the time of the first sound spike and projecting it onto the myogram for each muscle, that portion of the myogram showing electrical activity preceeding the spike was identified as the beginning of the chewing cycle.

I. Selection of Myograms for Study

The myograms from the first three chewing strokes or biting strokes of the right and left sides of duplicate exercises were selected for study. Hence, a total of thirty-six myograms taken from three muscles during the first three chewing strokes or biting strokes of the four chewing exercises of this experiment were analyzed and compared to the analagous chewing strokes or biting strokes in the previous experiments of this study. The myograms succeeding the first three chewing strokes or biting strokes were not studied because as chewing progressed the cough drop became an unmanageable tacky mass.

The chewing exercises were selected for two reasons. First, the act of chewing was mainly reflex in nature and therefore, relatively free from influence of both subject and experimenter. Secondly, chewing the selected medium subjected the teeth and their supporting structures, muscles and joints to stresses which tested their functional ability.

K. Defining Characteristics of the Myograms

The myograms contained two basic dimensions, amplitude and time. Relative amplitudes were studied along with the rates of change of amplitude with respect to time. There were sustained high, low or zero amplitudes. Peaks were defined as high amplitude of brief duration preceded and followed by rapid rates of change in amplitude. Noding was brief, low or zero amplitude bordered by rapid decrease and rapid increase in amplitude.

A chewing cycle was considered to be that period of time from the onset of one isometric contraction of the muscle to the onset of the next isometric contraction of that muscle, as determined from the electromyographic recording.

A chewing stroke or biting stroke was considered to be that portion of the chewing cycle which began with the onset of electrical activity and terminated with the end of electrical activity, as determined from the electromyographic recording.

The term "chewing stroke" may not be quite as accurate a term as "biting stroke", however, since that portion of the chewing cycle from the onset of electrical activity until the cessation of electrical activity has, in the previous parts of this longitudinal study been referred to as the "chewing stroke" it will be used in this paper along with the term "biting stroke" for the sake of continuity.

Duration of the muscular activity for each chewing stroke or biting stroke was studied as a whole and also divided into two components, onset of activity and end of activity. The rate of increase of amplitude at the onset of activity, and the rate of decrease of amplitude at the end of activity were also noted. Form of the electromyogram was analyzed for frequency of bursts of activity. To demonstrate the form graphically, lines were drawn on the myogram connecting spikes of minimum amplitude with spikes of maximum amplitude. The activity between the myograms of successive chewing strokes or biting strokes, termed "interim activity" was also indentified and studied.

L. Evaluation of the Electromyographic Data

Methods of Study

To gain a knowledge of the behavior of the temporal and masseter muscles within the experimental conidtions and to recognize the occurrence of any trends in their behavior during orthodontic treatment, the myograms from Experiment VII were analyzed and compared with those of the previous experiments. The myograms were studied in the following manner:

Method I Listing and evaluating the characteristics of the myograms for each individual subject.

Method II Analysis of initiation of chewing activity.

Method III Measuring the duration of the chewing stroke (biting stroke).

Method IV Analysis of the number of bursts in a chewing stroke (biting stroke).

The analysis of each method of study appears in the "FINDINGS".

Method I Listing and Evaluating Characteristics of the Myograms for Each Individual Subject

The following characteristics were grouped and grossly evaluated: bursts, amplitude, duration, noding, sustained low amplitude, rate of onset, rate of ending, interim activity, and initiation of chewing activity.

The rating scale used for evaluating all of the characteristics other than bursts and initiation of chewing activity, which were listed as counts, is as follows:

xxx	maximum
xx	moderate
x	minimum
0	absent

Method II Analysis of Initiation of Chewing Activity

The onset of electromyographic activity for each of the muscles in each of the first three chewing cycles of each exercise was marked on the myogram. Then a straight edge was held at right angles to the border of the paper so that it passed through the ink recordings of all three muscles. The straight edge was then moved along the recordings until it contacted the mark of the first muscle (or muscles) to begin electrical activity. The first muscle (or muscles) to begin electrical activity was then listed in chart form, the data from this experiment being added to that already at hand from the previous experiments in this study. This was done for all patients in this experiment, yielding a total of twelve tabulations for each patient. The results for all patients in each experiment were then totaled in chart form. The chart showed the number of times each muscle or muscle group initiated the chewing cycle in each experiment. The data from the table were then plotted as a series of graphs which appear in Part II of the "FINDINGS".

Method III Measuring the Duration of the Chewing Stroke (Biting Stroke)

The durations of the chewing strokes or biting strokes were expressed as percentages of the chewing cycles rather than by direct time measurement because the subjects did not chew at a uniform speed. The subjects were instructed to chew slowly because some individuals chewed so rapidly that chewing cycles were indistinguishable. The percentage values for each experiment were divided into arbitrary class intervals and the frequency of occurrence of the various percentages within each class interval were expressed as separate histograms for each experiment for Experiments I through VII. These appear in Part III of the "FINDINGS". The Chi Square Test was also applied to these data to see if a statistically significant difference existed between the seven experiments and between pairs of experiments.

Method IV Analysis of the Number of Bursts in a Chewing Stroke (Biting Stroke)

The number of bursts in each of the first three chewing strokes or biting strokes for each subject were counted and a random sample of these counts were taken from each subject. A statistical analysis was done to see if there was a statistically significant difference in the number of bursts per chewing stroke or biting stroke between those patients still wearing appliances and those with the appliances removed.

M. Amplitude

The absolute amplitude was not measured because of the many factors affecting its variability.

N. Statistical Discipline

This was basically a qualitative study and the analysis of the data was done on a relative basis. In the first experiment, Widen (1960) considered each subject as a separate experimental unit because the population was heterogeneous, due to the various malocclusions presented, and there were no prior data for comparison. As successive experiments were completed enough data were accumulated to permit the developing of meaningful statistical analyses. These analyses were applied to Methods III and IV.

Method III Duration of the Chewing Stroke or Biting Stroke Expressed as a Percentage of the Chewing Cycle

The length of each of the first three chewing cycles of all muscles for all subjects was measured. Then the length of the chewing stroke or biting stroke was calculated as a percentage of the chewing cycle. These percentages were then entered into a table in which the frequency of occurrence of percentages within each class interval was tabulated for each subject in this experiment. Then the total frequency of occurrences for each class interval for this experiment was calculated and added to the table of similar data already at hand from the previous six experiments. The data from each experiment were made into a separate histogram representing each individual experiment and appear in Part III of the "FINDINGS".

These data were then subjected to the Chi Square Test (see Part III of "FINDINGS" for Table of Chi Square Figures). The Null hypothesis would be: that the data are all drawn from one parent distribution and that they are statistically alike. This would mean that the pattern of chewing did not change significantly during the stages of orthodontic treatment that distinguished these seven experiments. The data were analysed in this manner and a statistically significant difference was found to exist beyond the .001 level of significance. The individual comparisons were then made between Experiments VI and VII and between

Experiments I and VII.

Method IV Analysis of the Number of Bursts in a Chewing Stroke (Biting Stroke)

The bursts of electrical activity in each of the first three chewing strokes or biting strokes of all muscles for all subjects were counted. A random sample of one-third of the data was taken from each subject using a random numbers table to determine the selections.

These data were then subjecte to an Analysis of Variance to determine if there was a statistically significant difference in the number of bursts of electrical activity in the chewing strokes or biting strokes of those subjects still wearing appliances as opposed to those who have already had the appliances removed. The Null hypothesis being, that there is no statistically significant difference between these two groups of subjects. This analysis could also show if there were statistically significant differences between the muscles studied and the sides (right and left) used in chewing or any interaction between these main effects. Since counts do not follow the normal distribution they are not amenable to the use of analysis of variance without transformation. The transformation used in this case was the square root of the observation plus one (1). A portion of the Data Sheet showing the transformed data used in this analysis appears in Figure 15. The Analysis of Variance Table showing the statistically significant differences appears in Part IV of the "FINDINGS".

SAMPLE DATA SHEET FOR ONE EXPERIMENT SHOWING TRANSFORMED DATA FOR ONLY TWO SUBJECTS

THE TRANSFORMATION USED WAS THE SQUARE ROOT OF THE OBSERVATION PLUS ONE (1).
THE OBSERVATIONS CONSISTED OF RANDOM SAMPLES FROM THE TOTAL DATA
OF THE NUMBER OF BURSTS IN A CHEWING STROKE.

WITH APPLIANCES

SIDES		RIGHT			LEFT		
MUSCLES		POST. TEMP.	MID. TEMP.	MASS.	POST. TEMP.	MID. TEMP	MASS.
SUBJ.	DUP. SUM DIFF.						
SUBJECT NO. 9 C. R.	A	1.73	1.73	1.73	1.41	1.41	1.41
	B	1.73	2.24	1.73	1.41	1.41	1.41
	SUM	3.46	3.97	3.46	2.82	2.82	2.82
	DIFF.	0	-.51	0	0	0	0

WITHOUT APPLIANCES

SIDES		RIGHT			LEFT		
MUSCLES		POST. TEMP.	MID. TEMP.	MASS.	POST. TEMP.	MID. TEMP.	MASS.
SUBJ.	DUP. SUM DIFF.						
SUBJECT NO. 10 H. S.	A	1.41	1.73	1.73	1.73	1.73	1.73
	B	1.73	1.41	1.73	2.24	1.73	2.
	SUM	3.14	3.14	3.46	3.97	3.46	3.73
	DIFF.	-.32	.32	0	-.51	0	-.27

FIGURE 15

A PORTION OF THE DATA SHEET USED IN THE ANALYSIS OF METHOD IV

CHAPTER III

FINDINGS

A. Introduction

The findings are based on the electromyographic recordings obtained from the first three chewing cycles of each chewing exercise performed by each of the sixteen subjects used in this experiment. The findings from this part of the study were also compared with those of the previous experiments in this longitudinal study, (Widen, Experiments I and II; Asahino, Experiment III; Shanahan, Experiment IV; Zylinski, Experiment V; and Fleming, Experiment VI).

Electromyographic recordings were taken this far in the longitudinal study during the following stages of orthodontic treatment:

Experiment I	Original malocclusion.
Experiment II	One day after placement of separating wires between the teeth.
Experiment III	One week after placement of separating wires between the teeth.
Experiment IV	One week after placement of the first archwires.
Experiment V	During anchorage preparation.

Experiment VI After completion of anchorage preparation.

Experiment VII During the final stages of orthodontic treatment.

This paper concerns itself with the electromyographic recordings taken during the final stages of orthodontic treatment before the removal of the active appliances.

The findings are presented in four parts corresponding to the four methods of study employed in this experiment (Experiment VII), which are described fully in "METHODS AND MATERIALS".

B. Part I

Part I of the "FINDINGS" contains the listing and evaluation of the various characteristics of the myograms for each individual subject in Experiments I through VII. This part is actually a qualitative evaluation of the following characteristics: amplitude, duration, noding, sustained low amplitude, rate of onset, rate of ending, interim activity; while bursts and initiation of chewing activity were listed quantitatively by means of counts.

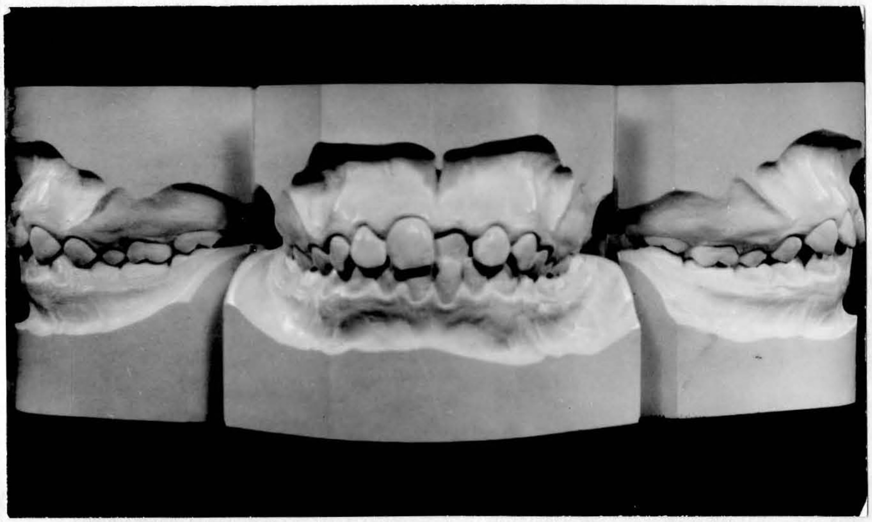
The object of this method of study was to note the changes in the electromyographic behavior of the muscles for each individual subject during the various stages of orthodontic treatment.

The characteristics of the myograms are listed in chart form for each individual subject along with photographs of the plaster casts of the original malocclusion and the Angle classification. (The experimental group consisted of three neutrocclusion and thirteen distocclusion cases.) An explanation of the treatment mechanics used at the time the electromyographic recordings were taken and intraoral photographs of the stage of treatment showing the appliance are included, as well as, a summary of the charted findings.

Subject #1 (L.C.) Age 16

Original Malocclusion

Angle Classification: Class I



Subject #1 (L.C.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.

Subject #1 (L.C.) Age 16

Class I (Angle)

Treatment:

A. No teeth were extracted.

B. Appliance design. (See Methods and Materials page 82.)

At the time electromyographic recordings were taken for Experiment VII, this subject already had the active appliance removed and was using a rubber finishing appliance for functional retention.

Evaluation of the Characteristics of the Myograms.

Bursts: Showed a steady increase from Experiment I to Experiment V, with the exception of Experiment II which showed a "multiburst" pattern. The number of bursts remained about the same in Experiment VI and decreased in Experiment VII.

Amplitude: Moderate in all experiments except Experiments III and VII which showed maximum amplitude.

Duration: Minimal in Experiments I and IV and moderate throughout the rest of the experiments.

Noding: Minimal in Experiment I and then moderate throughout the remaining experiments.

Sustained low amplitude: Absent until Experiment V when it appeared at the beginning of the stroke and remained in Experiments VI and VII.

Rate of onset: During the first four experiments this was maximal, but it decreased and became minimal in Experiments V and VI and moderate in Experiment VII.

Rate of ending: Maximal for the first four experiments and then became moderate in Experiments V and VI and minimum to moderate in Experiment VII.

Interim activity: Maximum throughout all experiments except for Experiments II, III and VII, when it was moderate.

Initiation of chewing activity: This subject showed a loss of synchronous initiation of activity from Experiment I to Experiment VI, while there was an increase in masseter initiation of the chewing stroke during the same time. There was very little difference in the muscles which initiated activity in Experiments IV, V, and VI. In Experiment VII, however, synchronous initiation of activity was restored beyond that occurring in Experiment I.

Conclusion:

This subject adapted only fairly well to the orthodontic procedures while the appliances were being worn, but showed an improved electromyographic pattern of muscular behavior after the removal of the active appliances, as shown by the decrease in noding and increase in synchronous initiation of chewing activity.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 1 L. C.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	1–2	xx	x	x	0	xxx	xxx	x
II	1–3	xx	xx	xx	0	xxx	xxx	xx
III	2–5	xxx	xx	xx	0	xxx	xxx	xx
IV	2–4	xx	x	xx	0	xxx	xxx	x
V	3–5	xx	xx	xx	x	x	xx	x
VI	3–5	xx	xx	xx	x	x	xx	x
VII	1–4	xxx	xx	xx	0	xx	xx	xx

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

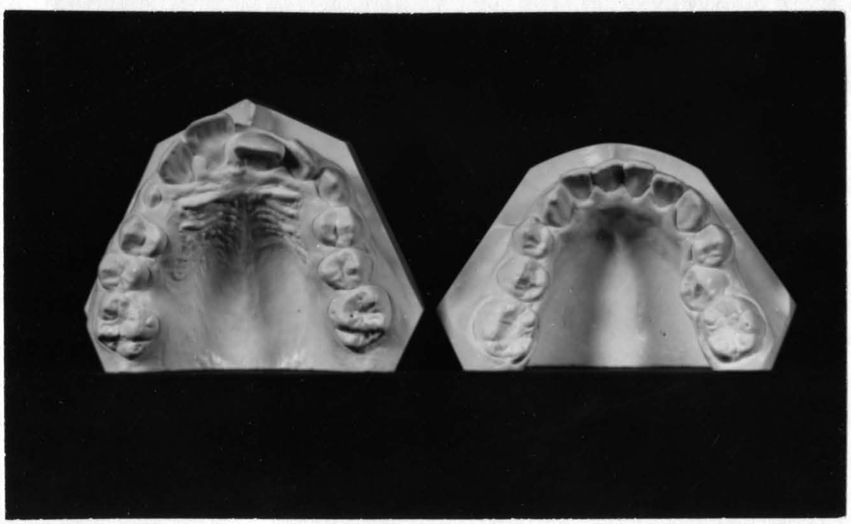
SUBJECT NUMBER: 1. L. C.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	1	3	2	5	5	4	1
Masseter and middle temporal first	0	0	0	1	0	0	0
Masseter and posterior temporal first	0	0	1	0	0	0	0
Middle and posterior temporal first	0	0	2	0	0	2	0
Middle temporal first	0	0	0	0	0	0	0
Posterior temporal first	1	2	0	0	1	0	0
All together (Synchrony)	10	7	7	6	6	6	11
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #2 (E.G.) Age 13

Original Malocclusion

Angle Classification: Class II - Division I



Subject #2 (E.G.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.

Subject #2 (E.G.) Age 13

Class II - Divsion 1 (Angle)

Treatment:

A. No teeth were extracted.

B. Appliance design. (See Methods and Materials page 82.)

At the time electromyographic recordings were taken for Experiment VII, this subject already had the active appliance removed and was using a rubber finishing appliance for functional retention.

Evaluation of the Characteristics of the Myograms.

Bursts: Experiments I through IV showed a similar number of bursts while Experiments V and VI showed an increase in the number of bursts and a decrease in Experiment VII.

Amplitude: Remained moderate in Experiments I through IV and then increased to maximum in Experiments V, VI and VII.

Duration: Maximum in Experiments I through IV and then became even longer in Experiments V and VI, decreasing to moderate in Experiment VII.

Noding: Maximum in Experiments I through IV, increased more in

Experiment V and increased still further in Experiment VI and then dropped to moderate in Experiment VII.

Sustained low amplitude: Progressively increased from none in Experiment I to maximum in Experiment VI, but occurred only in the masseter muscles. In Experiment VII was minimum to moderate and only in the middle and posterior temporal muscles.

Rate of onset: Remained moderate throughout all experiments.

Rate of ending: Moderate throughout except for and increase to maximum in Experiment V.

Interim activity: Maximum in Experiment I, decreased to minimum in Experiments III and IV, and became moderate again in Experiments V and VI, then dropped to minimum in Experiment VII.

Initiation of chewing activity: The onset of activity in Experiments I and II was fairly evenly divided between the masseters and synchrony of all muscles. Experiments IV and V showed that synchronous initiation of chewing activity predominated. In Experiment VI there was a preponderance of the initiation of activity by the middle and posterior temporals. In Experiment VII chewing activity was initiated mainly by synchronous action of all muscles.

Conclusion:

This subject exhibited difficulty in adapting to the orthodontic procedures and showed the most difficulty in chewing in Experiment VI. There was an improved electromyographic pattern of muscular behavior after the removal of the active appliances, as shown in Experiment VII, as shown by the increase in synchronous initiation of chewing activity and the decrease in noding or inhibition.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART I COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 2 E. G.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	4-6	XX	XXX	XXX	0	XX	XX	XXX
II	4-6	XX	XXX	XX	X	XX	XX	XX
III	4-6	XX	XXX	XXX	X	XX	XX	X
IV	4-5	XX	XX	XXX	X-MASS.	XX	XXX	X
V	6-8	XXX	XXX	XXX	XX-MASS.	XX	XXX	XX
VI	6-9	XXX	XXX	XXX	XXX-MASS.	XX	XX	XX
VII	2-5	XXX	XX-XXX	XX	XX-POST. TEMP.	XX	XX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

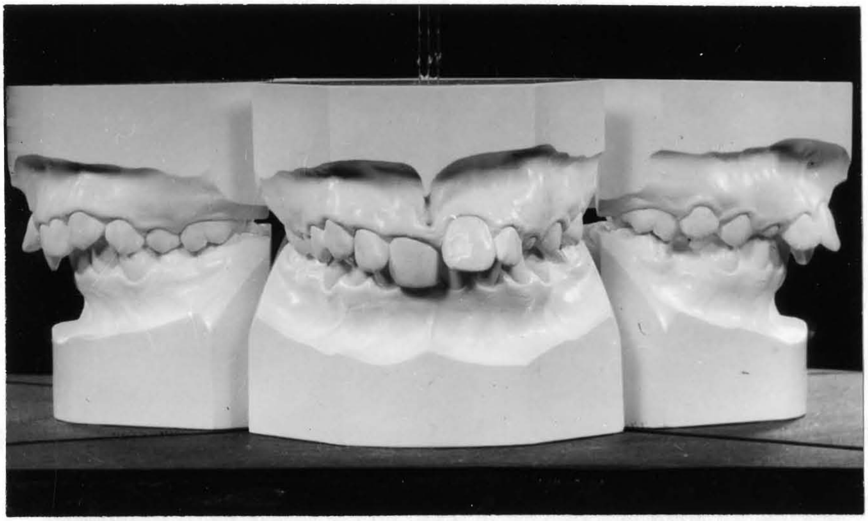
SUBJECT NUMBER: 2. E.G.

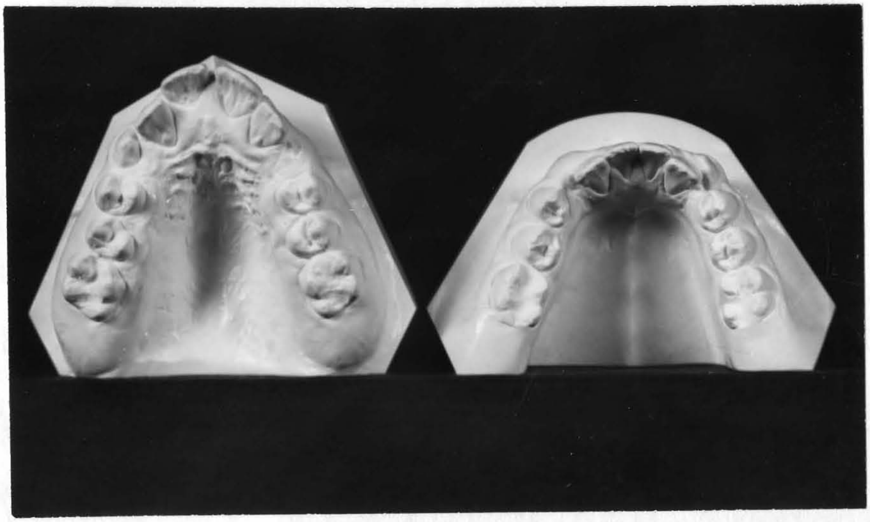
EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	4	4	6	4	1	2	0
Masseter and middle temporal first	1	0	2	0	0	0	0
Masseter and posterior temporal first	1	0	0	0	0	0	1
Middle and posterior temporal first	0	2	1	0	2	3	0
Middle temporal first	0	1	0	0	2	5	1
Posterior temporal first	0	1	0	0	0	0	2
All together (Synchrony)	6	4	3	8	7	2	8
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #3 (R.H.) Age 13

Original Malocclusion

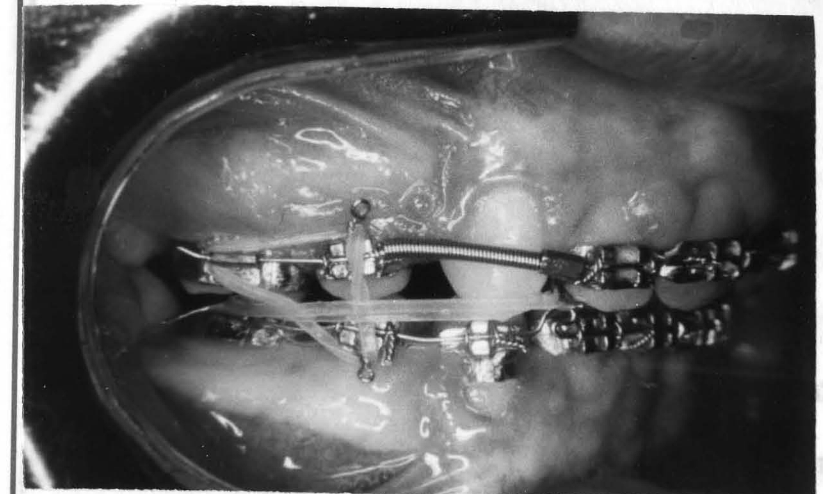
Angle Classification: Class II - Divsion I

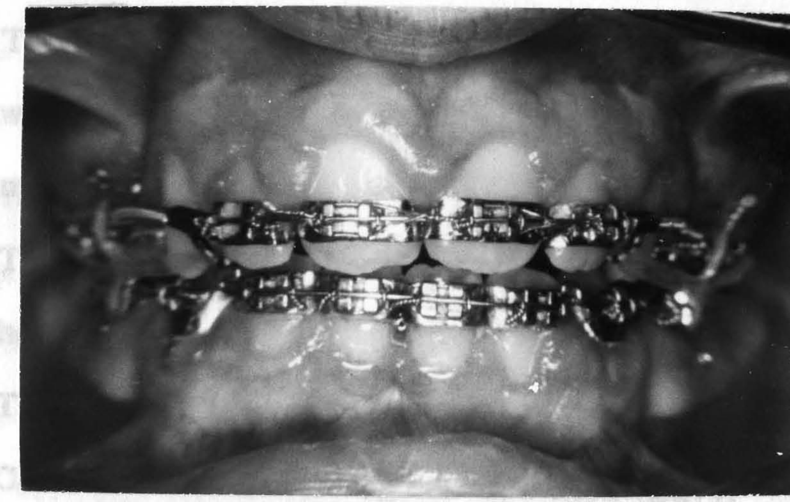




Subject #3 (R. H.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.





Subject #3 (R. H.) Age 13

Class II - Division 1 (Angle)

Treatment:

A. Extraction of the four first premolars.

B. Appliance design. (See Methods and Materials page 70, 75 and 81.)

The maxillary archwire was a straight (horizontal) archwire with attachments (coil spring and sliding hook) mesial to the upper second bicuspids.

The mandibular archwire was a consolidation archwire with horizontal hooks distal to the lower lateral incisors.

The elastics worn were buccal and lingual 1/4 inch light Class II's and the triangular 1/4 inch heavy.

Evaluation of the Characteristics of the Myograms.

Bursts: The range of the number of bursts in Experiments II, IV, V and VI was similar to that found in Experiment VII and approximately twice that found in Experiments I and II.

Amplitude: Moderate throughout all experiments except for an increase to maximum in Experiments III and VII.

Duration: Showed a progressive increase from minimum in Experiment I to a range of moderate to maximum in Experiments V, VI and VII.

Noding: Progressive increase throughout all experiments from minimum in Experiment I to maximum in Experiments VI and VII.

Sustained low amplitude: In the masseters throughout all experiments except in Experiment VII.

Rate of onset: Moderate throughout all experiments.

Rate of ending: Moderate throughout all experiments.

Interim activity: Moderate until Experiment V when it became minimum and remained as such in Experiments VI and VII.

Initiation of chewing activity: The masseters, which initiated some activity in Experiments I through IV, did not initiate activity during Experiments V and VI. The temporals, which initiated activity only a few times in the early experiments, became more prominant in their role as initiators of activity in Experiments IV, V and VI. Synchronous initiation of activity remained about the same for all experiments, except for an increase in Experiment II and a decrease in Experiment IV. In Experiment VII synchronous initiation of chewing activity on the part of all three muscles became dominant.

Conclusion:

This subject displayed moderate difficulty in adapting to the orthodontic procedures, but was beginning to show some improvement in the electromyographic pattern of muscular behavior in Experiment VII, as shown by the reduction in the number of nodes and the increase in synchronous initiation of chewing activity.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 3 R. H.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	1-3	XX-RT. X-LT.	X	X	X-LEFT MASS.	XX	XX	XX
II	1-3	XX	X	X-XX	X-MASS.	X	XX	X
III	3-6	XXX	XX	XX	X-LEFT MASS.	XX	XX	XX
IV	3-6	XX	XX	XX	X-MASS.	XX	XX	XX
V	2-6	XX	XX-XXX	XXX	X-MASS.	XX	X-XX	X
VI	3-5	XX	XX-XXX	XXX	X-MASS.	XX	XX	XX
VII	1-6	XXX	XXX	X-XXX	0	XX	XX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

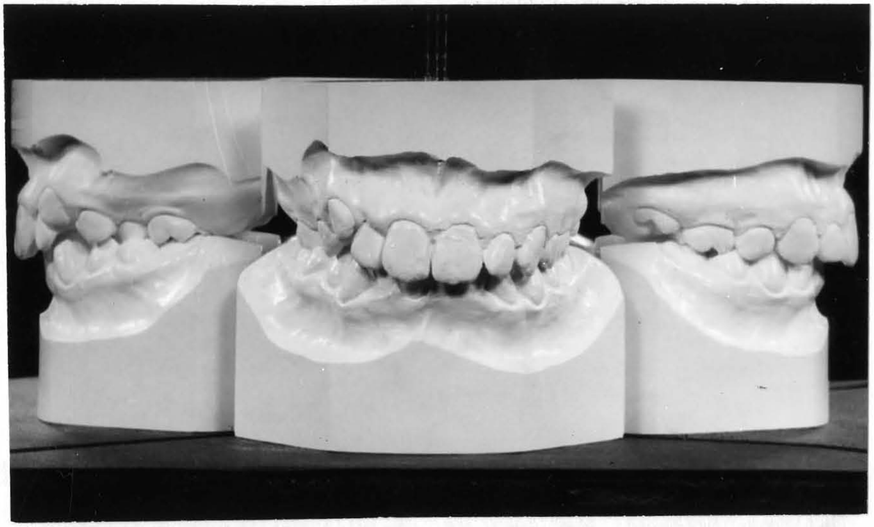
SUBJECT NUMBER: 3 R.H.

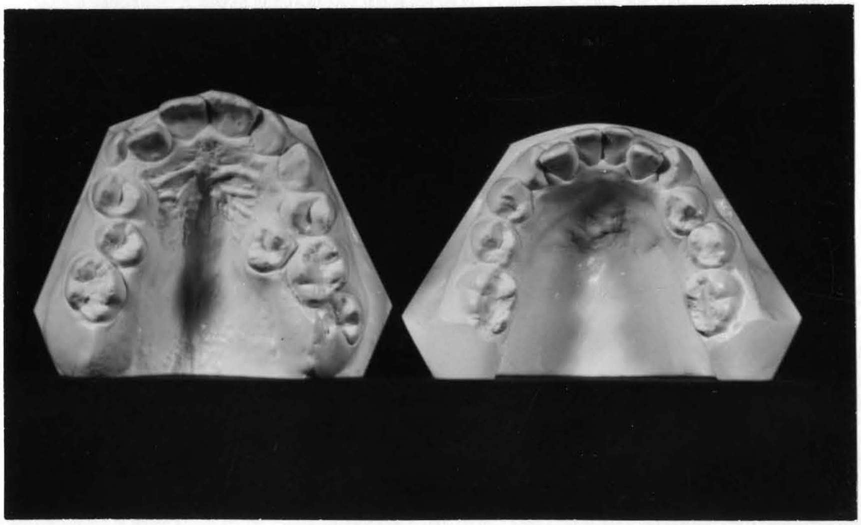
EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	3	2	3	2	0	0	2
Masseter and middle temporal first	0	1	1	1	0	0	0
Masseter and posterior temporal first	0	0	0	0	0	1	0
Middle and posterior temporal first	1	0	3	0	4	4	1
Middle temporal first	0	1	0	0	1	1	0
Posterior temporal first	3	0	0	8	2	2	0
All together (Synchrony)	5	8	5	1	5	4	9
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #4 (M.K.) Age 13

Original Malocclusion

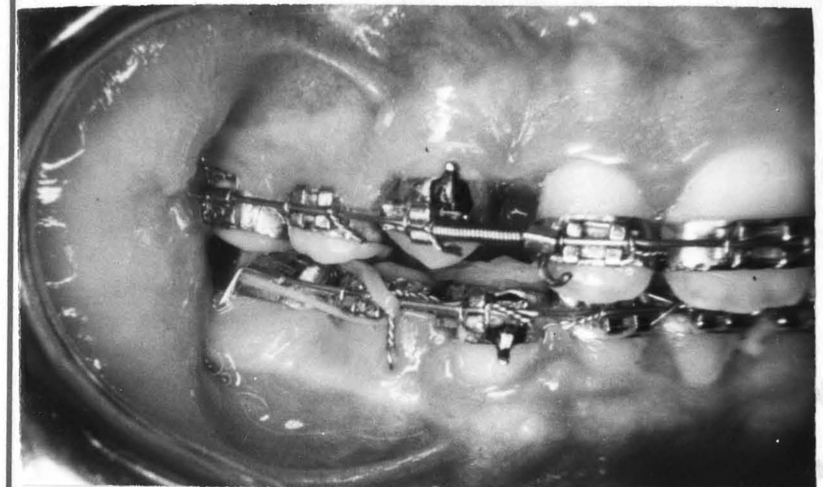
Angle Classification: Class II - Division 1 - Subdivision





Subject #4 (M.K.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.



Subject #4 (M.K.) Age 12

Class II - Division 1 - Subdivision

Treatment:

A. Extraction of the four first premolars.

B. Appliance design. (See Methods and Materials page 75.)

The maxillary archwire was a straight (horizontal) archwire with attachments (coil spring and sliding hook) to the mesial of the upper canines.

The mandibular archwire was a straight (horizontal) archwire with no attachments.

The elastics were worn in a Class II fashion and in a cross-bite fashion (triangular) as mentioned in Methods and Materials (page 81).

Evaluation of the Characteristics of the Myograms.

Bursts: Showed a low range in Experiments I and II, increased in Experiments III, IV and V, and then decreased back to the original range in Experiment VI, and then increased very slightly in Experiment VII.

Amplitude: Was moderate in Experiments I, III, IV, V and VII, minimum in Experiment II and maximum in Experiment VI.

Duration: Started out as minimal and increased to moderate in Experiments IV, V, VI and VII.

Noding: Remained moderate throughout until Experiment VI when it showed a decrease to minimum and then a return to moderate in Experiment VII.

Sustained low amplitude: Moderate in the masseters throughout all experiments.

Rate of onset: Moderate throughout the first five experiments and then maximum in Experiment VI and moderate again in Experiment VII.

Rate of ending: Moderate throughout the first five experiments and minimum in Experiment VI and them minimum to moderate in Experiment VII.

Interim activity: Minimum throughout the first six experiments except for Experiment II, and then minimum in Experiment VII.

Initiation of chewing activity: There was some variability in the muscles first to initiate activity. Experiments I and III were similar in that the muscles initiated activity synchronously or the masseters initiated activity, while in Experiments II and IV the masseters were the predominant muscles in initiating activity. In Experiments V and VI synchronous initiation was predominant, as was the case in Experiment VII.

Conclusion:

This subject seemed to have adapted well to the orthodontic procedures, as the muscular behavior exhibited little inhibition throughout treatment and a high percentage of the chewing strokes were initiated by concurrent activity of all three pairs of muscles.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 4 M.K.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	1-3	XX	X	XX	X-RT. MASS. & POST. TEMP.	XX	XX	X
II	1-3	X	X	XX	XX	XX	XX	XX
III	3-5	XX	X	XX	XX-RT. MASS. & POST. TEMP.	XX	XX	X
IV	2-4	XX	XX	XX	XX-RT. MASS.	XX	XX	X
V	2-4	XX	XX-XXX	XX	X-RT. MASS.	X-XX	XX	X
VI	1-3	XXX	XX	X	XX-MASS.	XX-XXX	XX-XXX	X
VII	2-5	XXX	XX	XX	LT. POST. & RT. MID. & POST. TEMP.-X	X-XX	X-XX	0

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

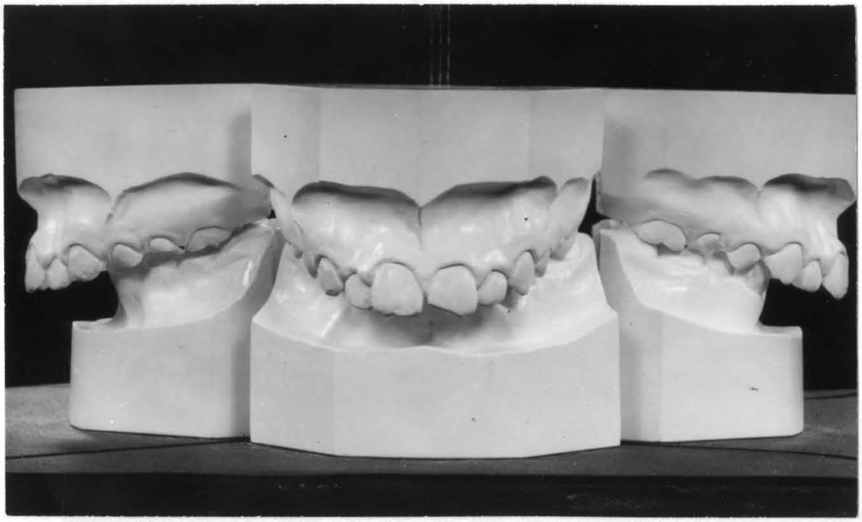
SUBJECT NUMBER: 4. M. K.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	6	7	4	8	1	0	1
Masseter and middle temporal first	1	0	0	0	0	1	1
Masseter and posterior temporal first	0	0	0	0	0	0	0
Middle and posterior temporal first	0	2	0	1	2	3	1
Middle temporal first	0	1	1	0	1	0	0
Posterior temporal first	0	0	0	1	0	0	2
All together (Synchrony)	5	2	7	2	8	8	7
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #5 (M.M.) Age 13

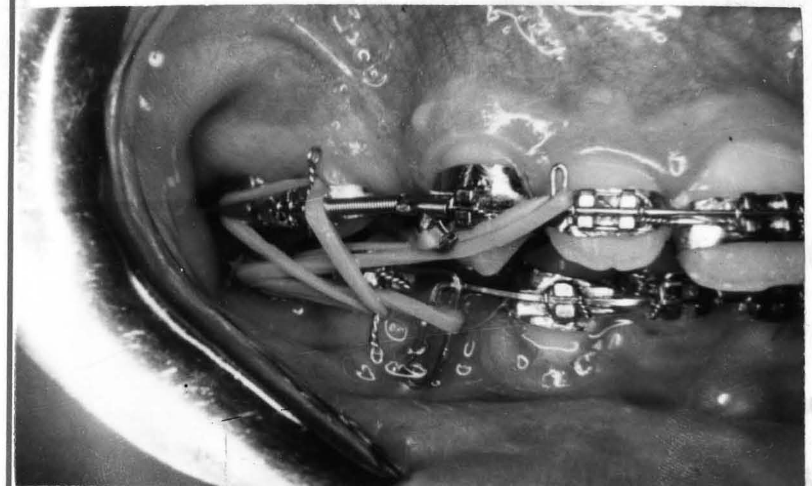
Original Malocclusion

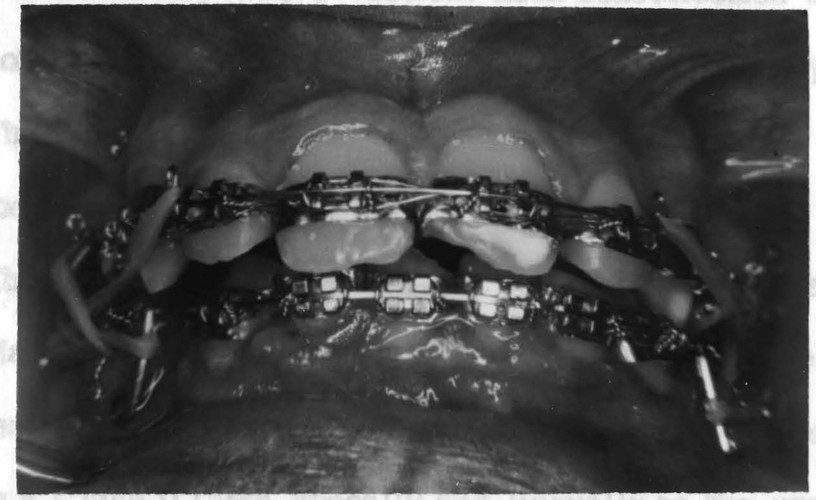
Angle Classification: Class II Division 1



Subject #5 (M.M.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.





Subject #5 (M.M.) Age 13

Class II Division 1 (Angle)

Treatment:

A. Extraction of the four first premolars.

B. Appliance design. (See Methods and Materials page 70 and 72.) The maxillary was a vertical hook consolidation archwire with coil spring and sliding hook to the upper second premolars. The mandibular archwire was a rectangular wire contraction loop archwire.

The elastics were of three types mentioned in Methods and Materials (page 81). There were intramaxillary elastics in the mandibular arch, and between arches, elastics were worn in a Class II (both buccally and lingually to the upper sliding hook) and a triangular fashion.

Evaluation of the Characteristics of the Myograms.

Bursts: The range of bursts was similar throughout, with slight increases in Experiments III and VI.

Amplitude: Minimal from Experiment I through Experiment IV and then became moderate in Experiments V and VI and then increased to maximum in Experiment VII.

Duration: Minimal in Experiment I through Experiment IV and became moderate in Experiments V, VI and VII.

Noding: Remained moderate throughout all experiments.

Sustained low amplitude: Remained minimal throughout all experiments except for an increase to moderate in Experiments IV and VII.

Rate of onset: Moderate in Experiments I through IV and became minimal in Experiments V and VI, then became moderate again in Experiment VII.

Rate of ending: Remained moderate throughout all experiments.

Interim activity: Minimum until Experiments VI and VII when it became moderate.

Initiation of chewing activity: From Experiment I to Experiment IV there was a decrease in the initiation of activity by the masseters and they did not initiate any activity in Experiments V or VI. The combination of middle and posterior temporals, on the other hand, failed to initiate any activity in Experiments I and II, but showed a steady increase in Experiments III, IV, and V, at which time they initiated almost all of the activity. The initiation of activity by the masseters decreased markedly in Experiment VI. Synchrony occurred fairly frequently in Experiment I, and showed a progressive decrease up to Experiment V, when it initiated activity only once. In Experiment VI synchrony initiated activity three-fourths of the time, while the combination of the middle and posterior temporals initiated activity the remaining times. Experiment V showed a predominance of the combination of the middle and posterior temporals initiating activity. Experiment VII showed a predominance of synchronous activity of all three muscles in initiating the chewing stroke.

Conclusion:

This subject showed good adaptation to the orthodontic procedures, exhibiting moderate noding and synchronous initiation of chewing activity by the three pairs of muscles.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 5 M. M.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-3	X	X	XX	X-MASS.	XX	XX	X
II	2-3	X	X	XX	X-MASS.	XX	XX	X
III	3-4	X	X	XX	X-MASS.	XX	XX	X
IV	2-3	X	X	XX	XX-MASS.	XX	XX	X
V	2-3	XX	XX	XX	XX-MASS.	X	XX	X
VI	3-4	XX	XX	XX	X-MASS.	X	XX	XX
VII	1-5	XXX	XX-XXX	XX	X-MASS. &POST. TEMP.	XX	XX	XX

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

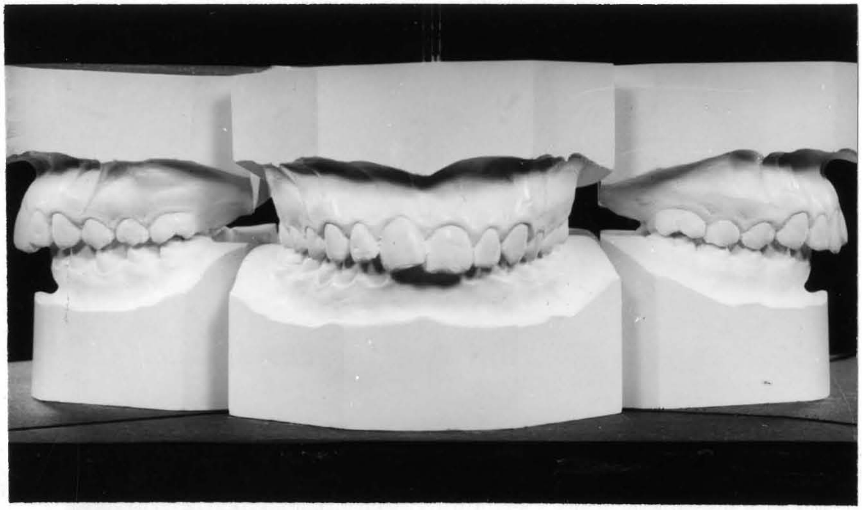
SUBJECT NUMBER: 5. M. M.

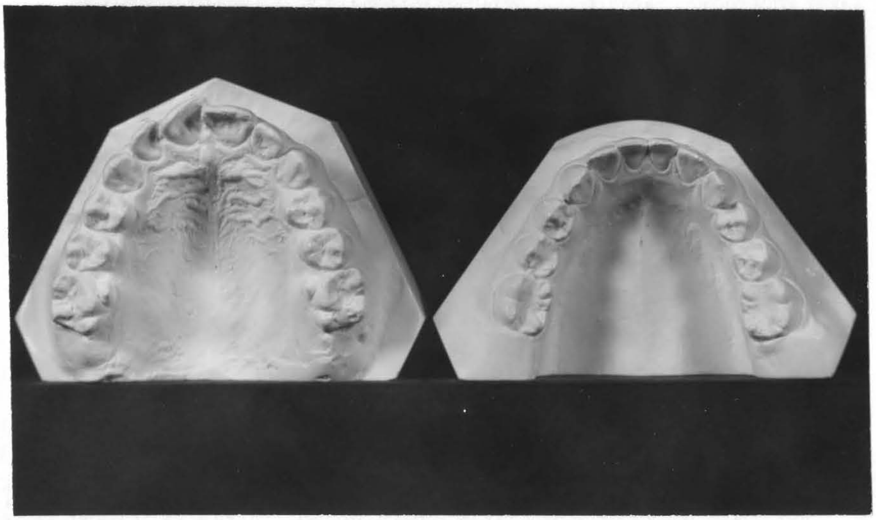
EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	6	7	3	2	0	0	0
Masseter and middle temporal first	0	1	0	0	0	0	0
Masseter and posterior temporal first	0	0	0	1	0	0	1
Middle and posterior temporal first	0	0	3	5	10	3	2
Middle temporal first	0	0	0	0	0	0	0
Posterior temporal first	1	0	3	1	1	0	0
All together (Synchrony)	5	4	3	3	1	9	9
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #6 (K.M.) Age 15

Original Malocclusion

Angle Classification: Class II Division 1





Subject #6 (K.M.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.

Subject #6 (K.M.) Age 15

Class II Division 1 (Angle)

Treatment:

A. No teeth were extracted.

B. Appliance design. (See Methods and Materials page 75.)

The maxillary archwire was a straight (horizontal) archwire with attachments (sliding hook and coil spring) to the mesial of the upper first premolars.

The mandibular archwire was a straight (horizontal) ideal archwire without attachments.

The elastics used were the Class II type (both buccal and lingual) as described in Methods and Materials (page 81).

Evaluation of the Characteristics of the Myograms.

Bursts: Remained relatively the same throughout all experiments and were never in a high range. Showed a slight drop in number in Experiment VII.

Amplitude: Varied from moderate to maximum.

Duration: Remained moderate throughout all experiments.

Noding: Remained about the same throughout all experiments, and showed a decrease in Experiment VII.

Sustained low amplitude: Occurred in the left masseter up to Experiment VI and then occurred in posterior temporal, during Experiment VII.

Rate of onset: Remained moderate throughout all experiments.

Rate of ending: Moderate throughout all experiments except for an increase to maximum in Experiment IV.

Interim activity: Maximum in the first three experiments and then moderate in the next three experiments continuing to be moderate in Experiment VII.

Initiation of chewing activity: The masseters, which at first predominated in the onset of activity, failed to initiate activity in the last four experiments. Generally, the temporals assumed a more important role in the onset of activity as the treatment progressed, except for Experiment V. Experiment III showed some possible confusion as nearly all muscle or combinations of muscles initiated activity. Experiment Vi showed the combination of the middle and posterior temporals along with synchrony of all muscles initiating all chewing activity. Experiment VII showed synchrony to be predominant in initiating of the chewing activity.

Conclusion:

This subject has adapted well to the orthodontic procedures, the muscular behavior showing only moderate noding or inhibition and the chewing activity being initiated mostly by concurrent action of the muscle.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 6 K. M.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	3-6	XX	XX	XXX	X-LEFT MASS.	XX	XX	XXX
II	2-5	XX	XX	XXX	X-LEFT MASS.	XX	XX	XXX
III	3-5	XX	XX	XXX	X-LEFT MASS.	XX	XX	XXX
IV	2-6	XXX	XXX	XXX	X-LEFT MASS.	XX	XXX	XX
V	2-5	XX	XX	XXX	X-LEFT MASS.	XX	XX	X-XX
VI	2-5	XXX	XX	XXX	X-LEFT MASS.	XX	XX	XX
VII	1-4	XXX	XX	XX	X-POST. TEMP. & LEFT MASS.	XX	XX	XX

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

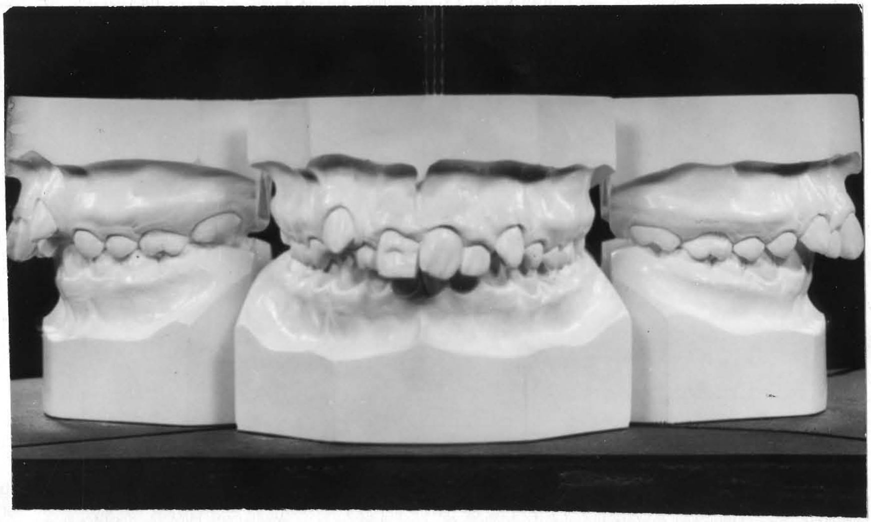
SUBJECT NUMBER: 6. K. M.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	8	2	3	0	0	0	1
Masseter and middle temporal first	0	1	1	1	0	0	0
Masseter and posterior temporal first	0	0	2	0	0	0	0
Middle and posterior temporal first	1	7	3	5	2	8	2
Middle temporal first	0	0	1	0	1	0	0
Posterior temporal first	0	1	0	4	0	0	0
All together (Synchrony)	3	1	2	2	9	4	9
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #7 (J. N) Age 15

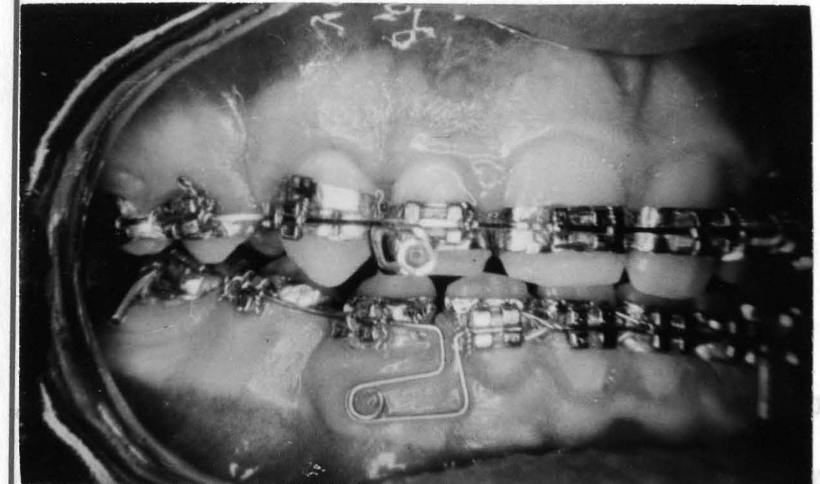
Original Malocclusion

Angle Classification: Class II Division I



Subject #7 (J. N.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.



olars.

nd Materials page 72.)

The maxillary archwire was a rectangular torquing archwire.

leveling

r teeth.

Evaluation c

Bursts r searching" pattern. Experiments V, VI, and VII showed more normal patterns of bursts.

Amplitude: Maximum

moderate in Experiments II

Noding: Remained mo

Sustained low amplitu

Rate of onset: Moder

Subject #7 (J.N.) Age 15

Class II Division 1 (Angle)

Treatment:

A. Extraction of the four first premolars.

B. Appliance design. (See Methods and Materials page 72.)

The maxillary archwire was a rectangular torquing archwire.

The mandibular archwire was a horizontal loop leveling archwire.

No elastics were worn.

High pull headgear was worn to the upper anterior teeth.

Evaluation of the Characteristics of the Myograms.

Bursts: Experiments I through IV exhibited a "multi-burst searching" pattern. Experiments V, VI, and VII showed more normal patterns of bursts.

Amplitude: Maximum in Experiments I, II, IV and VII, while it was moderate in Experiments II, V, and VI.

Noding: Remained moderate to maximum throughout all experiments.

Sustained low amplitude: Occurs occassionally in the right masseter.

Rate of onset: Moderate throughout all experiments.

Rate of ending: Moderate throughout all experiments.

Interim activity: Occurred as moderate throughout all experiments except Experiment VII where it was minimum.

Initiation of chewing activity: In this subject there was a definite absence of the temporal muscles initiating activity by themselves except in Experiment IV. The masseters and synchrony of all muscles were the predominant initiators of activity. A definite improvement in the onset of activity was noted in Experiment V and even more in Experiment VI, as synchrony of all muscles became the predominant group in initiating chewing activity, which was also shown in Experiment VII.

Conclusion:

This subject exhibited considerable difficulty in masticating during the early experiments but, by Experiment VI, adapted to the orthodontic procedures and by Experiment VII showed a very good electromyographic pattern of muscular behavior, as evidenced by the small number of nodes and the concurrent initiation of chewing activity by all the muscles studied.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 7 J. N.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	6-8	XXX	XX	XX	X-RIGHT MASS.	XX	XXX	XX
II	6-8	XXX	XXX	XXX	0	XX	XX	XX
III	6-8	XXX	XX	XX	X-RIGHT MASS.	XX	XX	X
IV	6-8	XX	XXX	XX	X-RIGHT MASS.	XX	XX	XXX-POST. TEMP.
V	2-5	XX	XX	XX	0	XX	XX	XX-MASS. & POST. TEMP.
VI	3-5	XX	XX	XX	X	XX	XX	XX-POST. TEMP.
VII	1-4	XX-XXX	XX	XX	X	XX	XX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

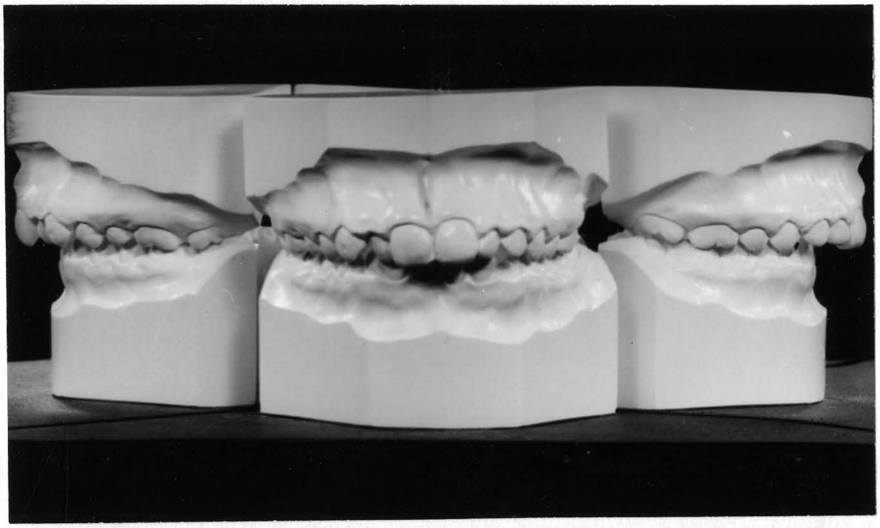
SUBJECT NUMBER: 7 J. N.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	3	7	5	4	4	1	1
Masseter and middle temporal first	2	2	0	0	1	0	0
Masseter and posterior temporal first	0	0	0	1	0	0	2
Middle and posterior temporal first	0	0	1	0	0	1	0
Middle temporal first	0	0	0	0	0	0	0
Posterior temporal first	0	0	0	5	0	1	0
All together (Synchrony)	7	3	6	2	7	9	9
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #8 (L.P.) Age 14

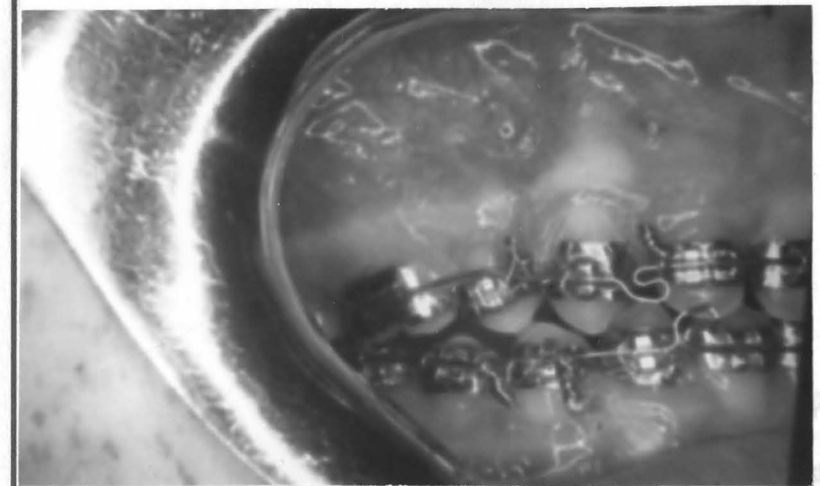
Original Malocclusion

Angle Classification: Class II Division 1



Subject #8 (L. P.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.



Subject #8 (L.P.) Age 14

Class II Division 1 (Angle)

Treatment:

A. Extraction of the maxillary first premolars.

B. Appliance design. (See Methods and Materials page 70.)

The maxillary archwire was a horizontal hook consolidation archwire.

The mandibular archwire was a horizontal hook consolidation archwire.

The elastics were of three types mentioned in Methods and Materials (page 81). Intramaxillary elastics were worn in the mandibular arch and between the arches, elastics were worn in a Class II and a triangular fashion.

Evaluation of the Characteristics of the Myograms.

Bursts: Remained relatively the same in all experiments except Experiments II and IV where there were "sustained searching patterns".

Amplitude: Maximum in all experiments except II and IV.

Duration: Increased from minimum in Experiment I to maximal in Experiment IV and then decreased slightly in Experiments V, VI and became moderate in VII.

Noding: Maximum throughout except for Experiment II where it decreased to moderate and Experiment VII where it was variable.

Sustained low amplitude: Predominantly in the masseter throughout all experiments, but also occurred occassionally in other muscles.

Rate of onset: Remained moderate throughout all experiments except for a decrease to minimum in Experiment IV.

Rate of ending: Moderate throughout all experiments except for a decrease to minimum in Experiment IV.

Interim activity: Maximum in masseters until Experiment V when it decreased to moderate and then became minimum in Experiment VI and ranged from minimum to maximum in Experiment VII. The posterior temporals exhibited moderate interim activity in Experiment VI only.

Initiation of chewing activity: The onset of activity between experiments remained relatively the same throughout all experiments except that in Experiment VI the pattern became more stable, with only synchronous activity of the muscles initiating chewing. However, in Experiment VII initiation of chewing activity occurred by almost all combinations of muscles with the masseters being predominant.

Conclusion:

Up to this point the subject had adapted well to the orthodontic procedures but is having some difficulty in adapting during this final stage of treatment, as shown by the increase in the number of nodes (or amount of inhibition) and the decrease in the number of times the chewing activity was initiated synchronously by the three muscle pairs.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 8 L. P.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-6	XXX	X	XXX	X-MID. TEMP.	XX	XX	XXX
II	2-5	XX	XX	XX	X-MASS. & MID. TEMP.	XX	XX	XX
III	2-6	XXX	X	XXX	X-MASS.	XX	XX	XXX
IV	2-6	XX	XXX	XXX	X	X	X	XXX
V	2-6	XXX	XX-XXX	XXX	X-MASS.	XX	XX	XX
VI	3-6	XXX	XX-XXX	XXX	XX-MASS.	XX	XX	XXX
VII	1-8	XXX	XX	XX	XX	XX	XX	XX-XXX

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

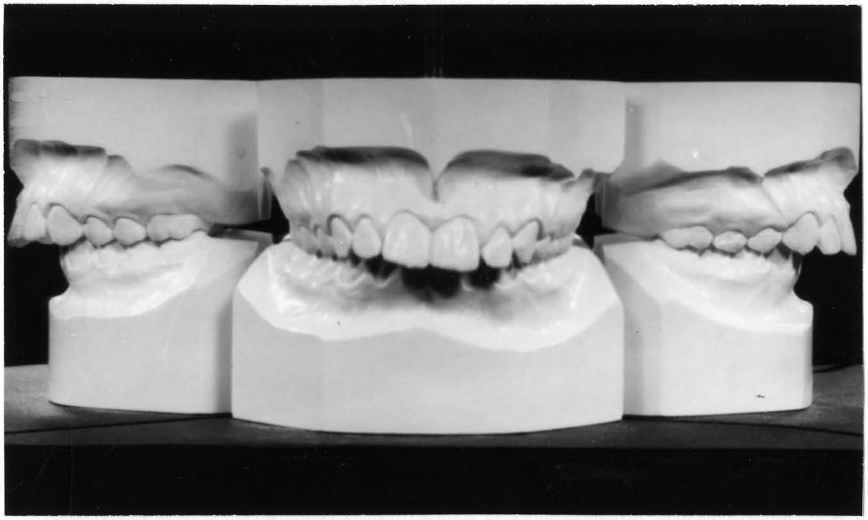
SUBJECT NUMBER: 8. L. P

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	6	5	5	5	3	5	5
Masseter and middle temporal first	0	0	0	1	0	0	1
Masseter and posterior temporal first	0	0	1	1	0	0	0
Middle and posterior temporal first	2	4	3	1	3	0	1
Middle temporal first	0	0	0	0	1	0	2
Posterior temporal first	0	0	0	1	0	0	1
All together (Synchrony)	4	3	3	3	5	7	2
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #9 (C. R.) Age 13

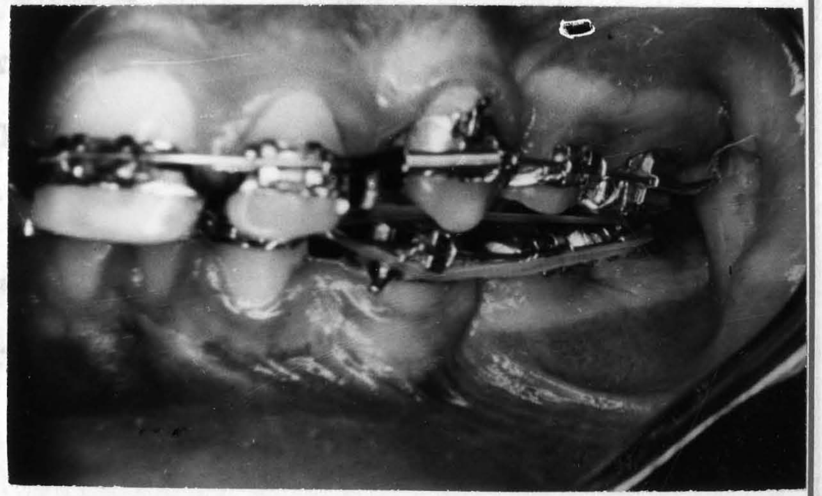
Original Malocclusion

Angle Classification: Class II Division 1



Subject #9 (C. R.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.



Subject #9 (C. R.) Age 13

Class II Division 1 (Angle)

Treatment:

A. Extraction of the four first premolars.

B. Appliance design. (See Methods and Materials page 70 and 75.)

The maxillary archwire was a straight (horizontal) archwire with attachments (coil spring and sliding hook) to the mesial of the upper cuspids.

The mandibular archwire was a horizontal hook consolidation archwire.

The elastics used were of two types described in Methods and Materials (page 81). There were intramaxillary elastics in the mandibular arch, and between the arches, elastics were worn in a Class II and a triangular fashion.

Evaluation of the Characteristics of the Myograms.

Bursts: Experiments I through IV showed almost entirely "multi-bursts". In Experiments V and VI there was a definite decrease in the number of bursts with Experiment VI showing the least number of bursts for any experiment. Experiment VII showed about as many bursts as

Experiment VI.

Amplitude: Moderate throughout all experiments except for some increase in Experiments III and IV and an increase to maximum in Experiment VII.

Duration: Moderate throughout all experiments except for an increase to maximal in Experiment IV.

Noding: Maximum throughout all experiments except for decreases to moderate in Experiments II, VI and VII.

Sustained low amplitude: Occurred in the masseters throughout, but became less in Experiments V and VI and disappeared in Experiment VII.

Rate of onset: Remained moderate throughout all experiments.

Rate of ending: Moderate throughout the first five experiments, but became minimal in Experiment VI and then returned to moderate in Experiment VII.

Interim activity: Minimum throughout all experiments.

Initiation of chewing activity: The occurrence of synchronous onset remained about the same in Experiments I through IV and then increased markedly in Experiments V and VI and then again in VII. The masseters, which at first initiated activity about one-third of the time, did not initiate activity in Experiments IV and V and only once in Experiment VI and once in Experiment VII. The combination of the middle and posterior temporals initiated activity only infrequently in the first three experiments. In Experiment IV they initiated activity one-half of the time, but their frequency of initiation of activity decreased to about one-fourth of the time in Experiments V and VI and not at all in Experiment VII.

Conclusion:

This subject, after having experienced considerable difficulty in the early experiments, seemed to have adapted well to the orthodontic procedures, showing a high percentage of initiation of chewing activity by synchronous action of the muscles and a decrease in noding.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 9 C. R.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	6-8	X-XX	XX	XXX	X-MASS.	XX	XX	X
II	6-8	X-XX	XX	XX	X-MASS.	XX	XX	X
III	6-8	XX-XXX	XX	XXX	0	XX	XX	X
IV	6-8	X-XXX	XXX	XXX	X-MASS.	X	XX	X
V	2-6	X-XX	XX-XXX	XXX	X-MASS.	XX	X-XX	X
VI	2-4	X-XX	XX	XX	X-MASS.	XX	X	X
VII	1-5	XXX	XX	X-XX	0	X-XXX	X-XX	X-XX

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

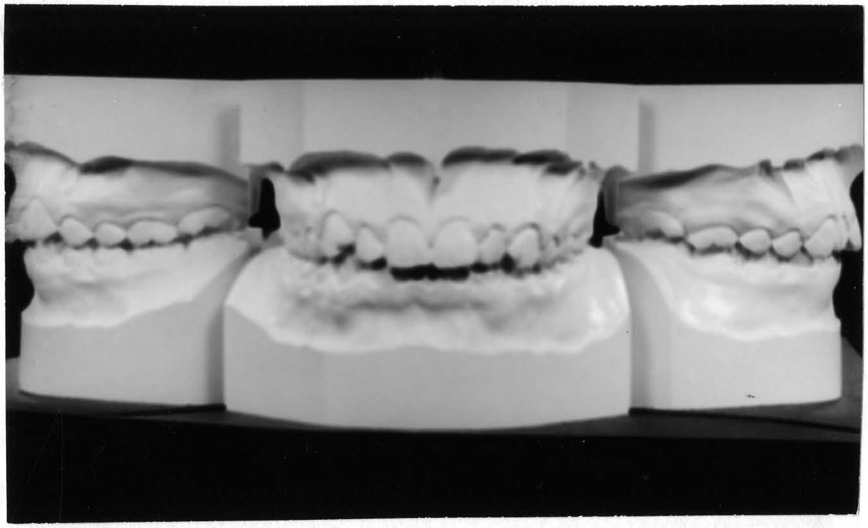
SUBJECT NUMBER: 9. C. R.

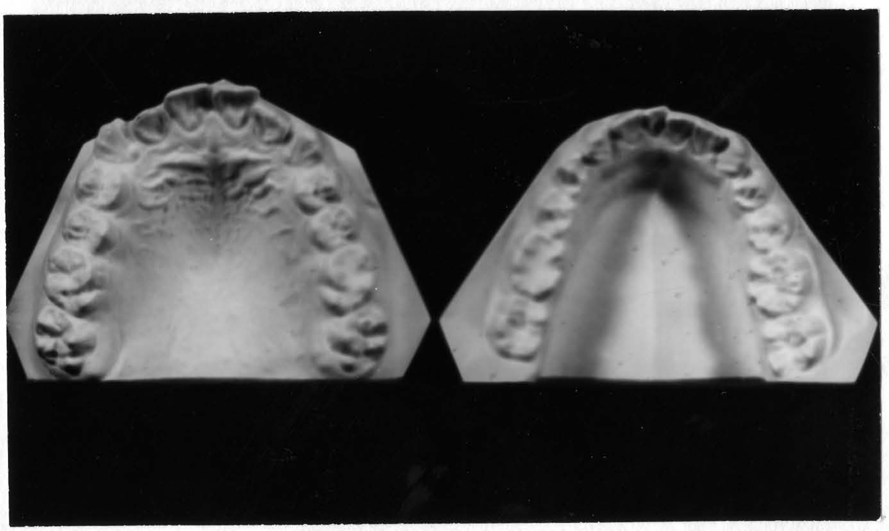
EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	3	4	3	0	0	1	1
Masseter and middle temporal first	0	0	0	0	0	0	0
Masseter and posterior temporal first	0	0	1	0	0	0	1
Middle and posterior temporal first	2	2	1	6	3	3	0
Middle temporal first	0	0	0	1	0	0	0
Posterior temporal first	2	2	1	1	0	0	0
All together (Synchrony)	5	4	6	4	9	8	10
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #10 (H. S.) Age 16

Original Malocclusion

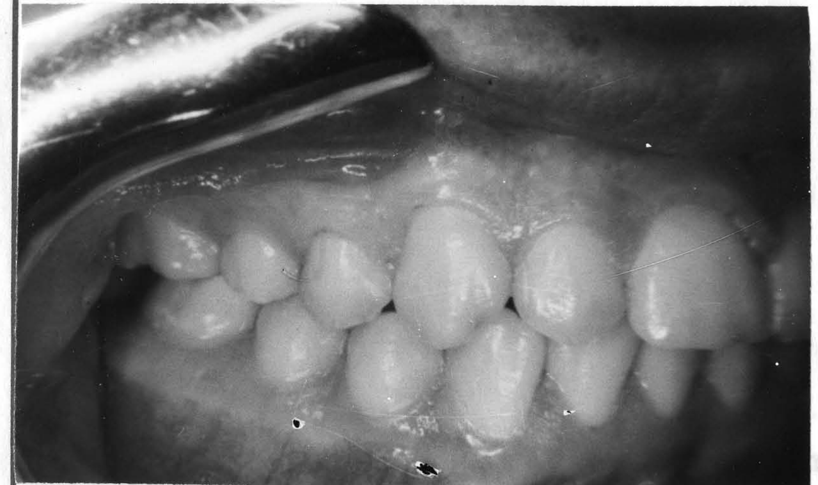
Angle Classification: Class I





Subject #10 (H. S.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.



nd Materials page 82.)

At the time electromyographic recordings were taken for

Amplitude: Maximum throughout all experiments except for a decrease to moderate in Experiments IV and V.

Subject #10 (H.S.) Age 16

Class I (Angle)

Treatment:

A. No teeth were extracted.

B. Appliance design. (See Methods and Materials page 82.)

At the time electromyographic recordings were taken for Experiment VII, this subject already had the active appliance removed and was using a rubber finishing appliance for functional retention.

Evaluation of the Characteristics of the Myograms.

Bursts: Showed a gradual increase in number from Experiment I to Experiment VI and then decreased in Experiment VII.

Amplitude: Maximum throughout all experiments except for a decrease to moderate in Experiments IV and V.

Duration: Showed an increase from minimum in the first three experiments to almost maximum in Experiments V, VI and VII.

Noding: Increased progressively from minimum in Experiment I to maximum in Experiments V and VI and then minimum in Experiment VII.

Sustained low amplitude: Minimum until Experiment V when it showed an increase in the masseter. It decreased in Experiment VI and became evident again in Experiment VII.

Rate of onset: Remained moderate throughout all experiments.

Rate of ending: Remained maximum throughout all experiments.

Interim activity: Minimum in all experiments except IV. VI and VII where it was moderate.

Initiation of chewing activity: The masseters initiated activity a relatively constant number of times except in Experiments III and IV, when they did not initiate activity at all. Synchronous initiation of activity occurred in nearly one-half of the cases in all of the experiments except VI. In Experiment VI, the middle and posterior temporals initiated activity most frequently. In Experiment VII synchronous initiation of activity occurred in three-fourths of the cases.

Conclusion:

This subject appeared to be having difficulty adapting to the orthodontic procedures, but in Experiment VII there is a recognizable improvement in the electromyographic pattern of muscular behavior. This is shown by a considerable decrease in noding or amount of inhibition during mastication and an increase in concurrent initiation of chewing activity by the muscles.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 10 H. S.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-3	XXX	X	X	X-MASS.	XX	XXX	X
II	2-3	XXX	X	X	X	XX	XXX	X
III	2-4	XXX	X	XX	X-MASS.	XX	XXX	X
IV	2-6	XX	XX	XX	0	XX	XXX	XX
V	3-6	XX-XXX	XXX	XXX	XX-XXX MASS.	XX	XXX	X
VI	4-7	XXX	XX-XXX	XXX	XX-MASS.	XX	XXX	X
VII	1-4	XXX	XXX	X-XXX	X-POST. TEMP. & MASS.	X-XXX	X-XXX	X-XX

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

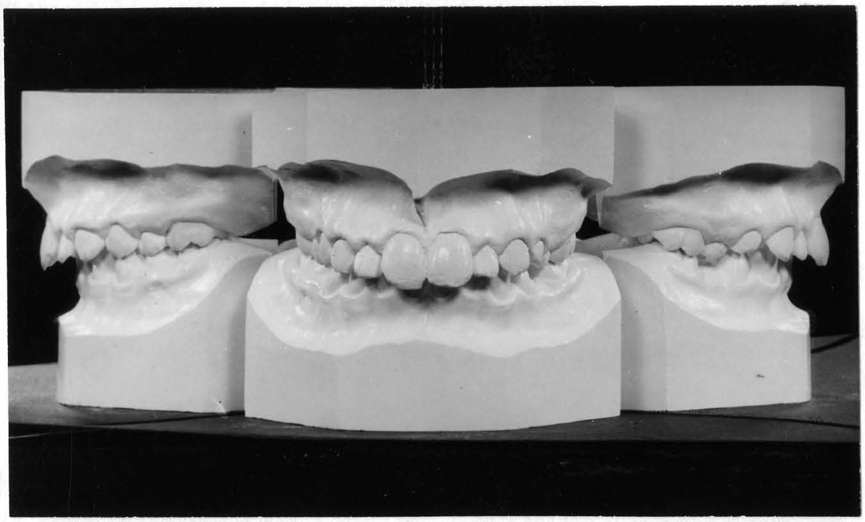
SUBJECT NUMBER: 10. H. S.

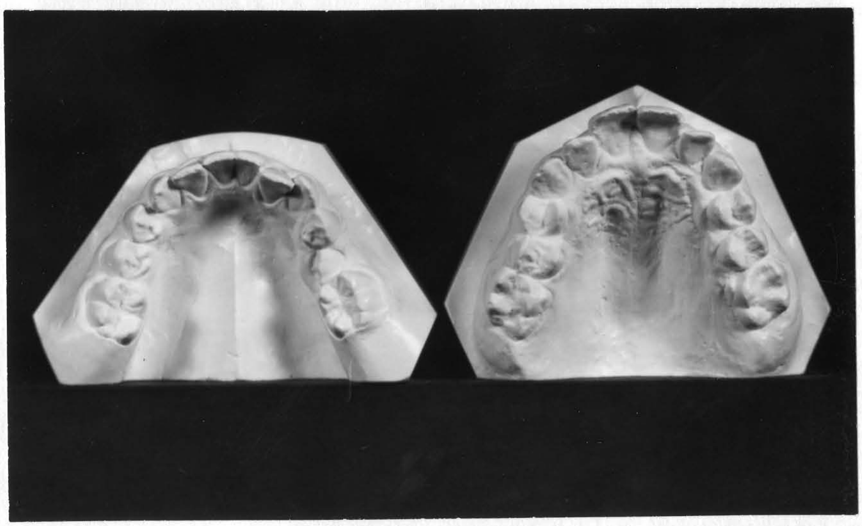
EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	2	3	0	0	3	2	3
Masseter and middle temporal first	1	1	2	1	0	0	1
Masseter and posterior temporal first	0	0	1	0	0	0	0
Middle and posterior temporal first	3	1	5	3	3	5	0
Middle temporal first	1	1	0	0	0	0	0
Posterior temporal first	0	0	0	2	0	2	0
All together (Synchrony)	5	6	4	6	6	3	8
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #11 (E.S.) Age 14

Original Malocclusion

Angle Classification: Class II Division 1





Subject #11 (E.S.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.

Subject #11 (E.S.) Age 14

Class II Division 1 (Angle)

Treatment:

A. No teeth were extracted.

B. Appliance design. (See Methods and Materials page 75.)

The maxillary archwire was a straight (horizontal) archwire with sliding yokes to the upper first molars.

The mandibular archwire was a straight (horizontal) archwire without attachments.

The elastics used were of the Class II type, between the arches, as described in the Methods and Materials (page 81).

Evaluation of the Characteristics of the Myograms.

Bursts: A "multi-burst searching" pattern was evident throughout except for Experiment V and Experiment VII. Experiment VI showed a return of the "searching" pattern.

Amplitude: Remained moderate until Experiments V and VI, which showed maximum amplitude in the posterior temporals and minimum amplitude in the masseters. Amplitude in Experiment VII was moderate.

Duration: Duration on the left side was maximum throughout while that on the right side was moderate until Experiment VI, when it increased to maximum. Duration in Experiment VII was moderate.

Noding: Moderate throughout all experiments except for an increase to maximum in Experiments III and VI.

Sustained low amplitude: Evident in the right masseter throughout all experiments except for Experiment IV. In Experiments V and VI the left masseter also showed sustained low amplitude. The masseters showed sustained low amplitude again in Experiment VII.

Rate of onset: Moderate throughout all experiments.

Rate of ending: Moderate for Experiments I through IV, but decreased slightly in Experiments V, VI and VII.

Interim activity: Maximum to moderate for the first four experiments. In Experiments V and VI it decreased to minimum, but returned to moderate in Experiment VII.

Initiation of chewing activity: In Experiments I through III the onset of activity showed some confusion as nearly all muscles or groups of muscles participated in initiating chewing activity. In Experiment IV, synchronous initiation and initiation by the temporals showed more predominance. In Experiment V, three-fourths of the chewing strokes were initiated by a synchrony of all the muscles. In Experiment VI, the middle and posterior temporals as a group and synchrony of all muscles predominated in initiating the chewing stroke. The same pattern of initiation was followed in Experiment VII as in Experiment VI.

Conclusion:

This subject exhibited a confused muscular pattern of behavior and appeared to be having some difficulty in adapting to the orthodontic procedures until Experiment VII where there is an improvement in the muscular behavior as detected electromyographically.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 11 E. S.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-7	XX	XX-XXX	XX	X-MASS.	XX	XX	XX-XXX
II	2-7	XX	XXX	XX	X-MASS.	XX	XX	XX-XXX
III	2-7	X	XX-XXX	XXX	X-MASS.	XX	XX	XX
IV	2-7	XX	XX-XXX	XX	0	XX	XX	X-XXX
V	2-6	X-XXX	XX-XXX	XX	X-MASS.	XX	X-XX	X
VI	2-7	X-XXX	XXX	XXX	X-MASS.	XX	X-XX	X
VII	2-6	X-XXX	XX	XX	X-MASS.	XX	X-XX	XX

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

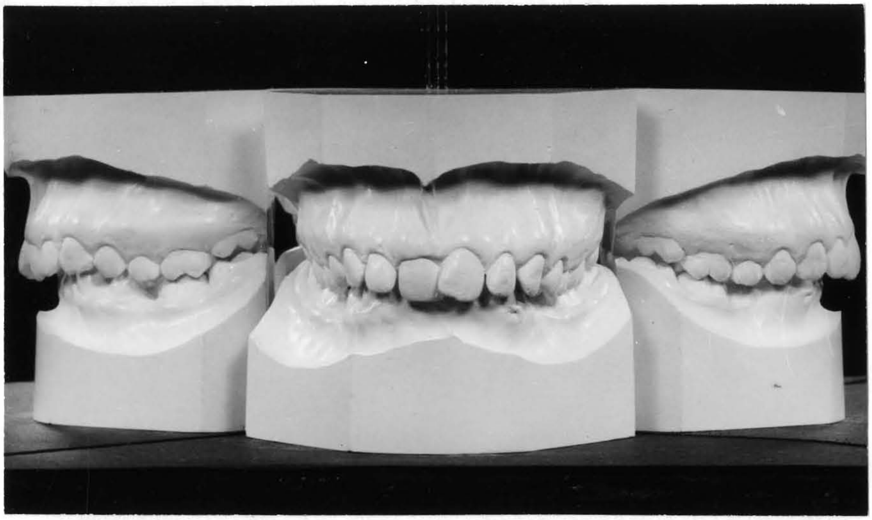
SUBJECT NUMBER: 11. E. S.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	3	5	4	2	1	0	1
Masseter and middle temporal first	1	1	1	0	0	0	0
Masseter and posterior temporal first	0	1	2	0	0	0	0
Middle and posterior temporal first	1	2	2	2	1	7	5
Middle temporal first	0	0	1	0	0	0	0
Posterior temporal first	0	1	0	3	1	0	0
All together (Synchrony)	7	2	2	5	9	5	6
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #12 (J. S.) Age 16

Original Malocclusion

Angle Classification: Class II Division 1



Subject #12 (J.S.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.

nd Materials page 75.)

Maxillary archwire was a straight (horizontal) archwire

Evaluation of

Bursts: ... "multi-burst" pattern. In Experiments V, VI and VII this decreased to a more normal pattern of three to six burs

Amplitude: Remained

ments.

Duration: Showed a re

I and III, while an increase

Subject #12(J.S.) Age 16

Class II Division 1 (Angle)

Treatment

A. No teeth were extracted.

B. Appliance design. (See Methods and Materials page 75.)

Maxillary archwire was a straight (horizontal) archwire with a sliding hook to the upper right first premolar.

The mandibular archwire was a straight (horizontal) ideal archwire.

The elastics used were the Class II type as described in Methods and Materials (page 81).

Evaluation of the Characteristics of the Myograms.

Bursts: In Experiments I through IV there was a "multi-burst" pattern. In Experiments V, VI and VII this decreased to a more normal pattern of three to six bursts.

Amplitude: Remained moderate to maximum throughout all experiments.

Duration: Showed a range of minimum to moderate in Experiments I and III, while an increase to a range of moderate to maximum was evident in Experiment II and IV. In Experiments V and VI the duration decreased to minimum, and returned to moderate in Experiment VII.

Noding: Remained minimum to moderate for the first five experiments, but showed an increase to maximum in Experiment VI and returned to moderate in Experiment VII.

Sustained low amplitude: Absent until Experiment VI, when it appeared in the masseters and showed again in Experiment VII.

Rate of onset: Moderate throughout all experiments.

Rate of ending: Moderate for the first five experiments, increased to maximum in Experiment VI and then dropped to minimum in Experiment VII.

Interim activity: Remained the same throughout the first six experiments and then became moderate in Experiment VII.

Initiation of chewing activity: In Experiments I through III the masseter was quite evident as an initiator of activity. A decrease in masseter initiation was evident in Experiment IV and there was no masseter initiation of activity in Experiments V and VI. Synchronous initiation of activity remained relatively stable in Experiments I through IV, but showed a predominance in Experiment V. Experiment VI showed a definite decrease in the occurrence of synchrony initiating the chewing stroke to the fewest number of times of any experiment. The temporals, which rarely initiated activity throughout the first five experiments, became the predominant muscles of initiation of the chewing stroke in Experiment VI. In Experiment VII the role of initiation of chewing activity was more or less divided between the temporals and synchronous activity on the part of all three.

Conclusion:

This subject exhibited some difficulty in chewing during Experiments I through IV, but showed good adaptation to the orthodontic procedures in Experiments V, VI and VII, as shown by the increase in synchronous initiation of chewing activity by all three pairs of muscles.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 12 J.S.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-8	XX-XXX	X-XXX	X-XXX	0	XX	XX	X-XXX
II	2-8	XX-XXX	XX-XXX	XXX	0	XX	XX	XX-XXX
III	2-8	XX-XXX	X-XXX	XXX	0	XX	XX	X-XXX
IV	2-8	XX-XXX	XX-XXX	XXX	0	XX	XX	X
V	3-5	XX-XXX	XXX	XXX	0	XX	XX	X-XXX
VI	[illegible]-5	XX-XXX	XXX	XXX	X-MASS.	XX	XXX	X-XX
VII	2-8	XX-XXX	XXX	XXX	X-POST. TEMP.	XX-XXX	XX-XXX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

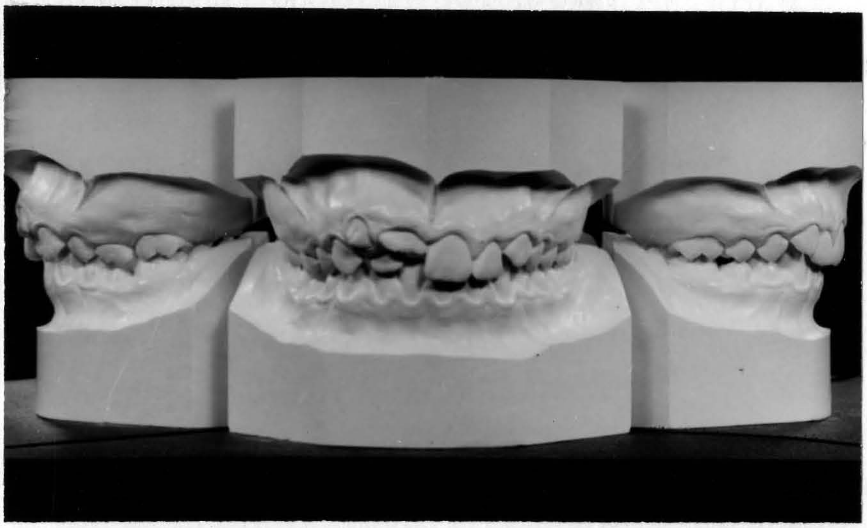
SUBJECT NUMBER: 12. J.S.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	5	7	4	2	0	0	0
Masseter and middle temporal first	1	1	0	0	1	0	0
Masseter and posterior temporal first	1	1	0	1	0	0	0
Middle and posterior temporal first	2	0	1	3	1	7	1
Middle temporal first	0	0	1	1	0	0	0
Posterior temporal first	0	0	2	1	0	3	2
All together (Synchrony)	3	3	4	4	10	2	9
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #13 (A.S.) Age 13

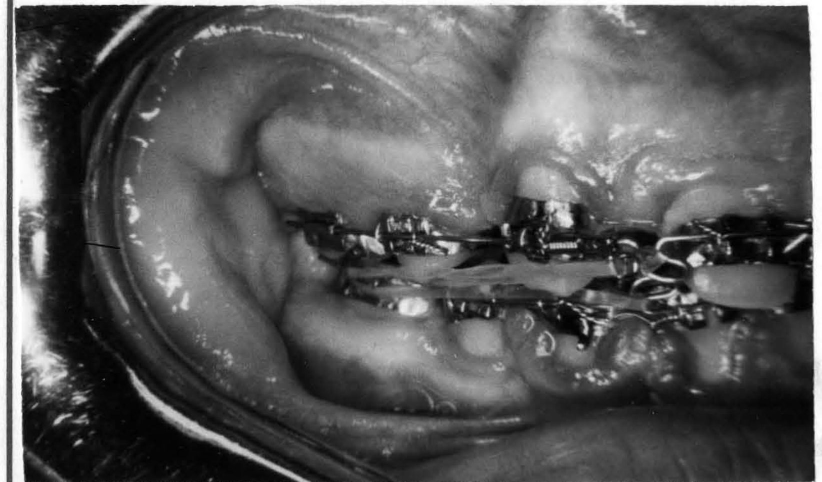
Original Malocclusion

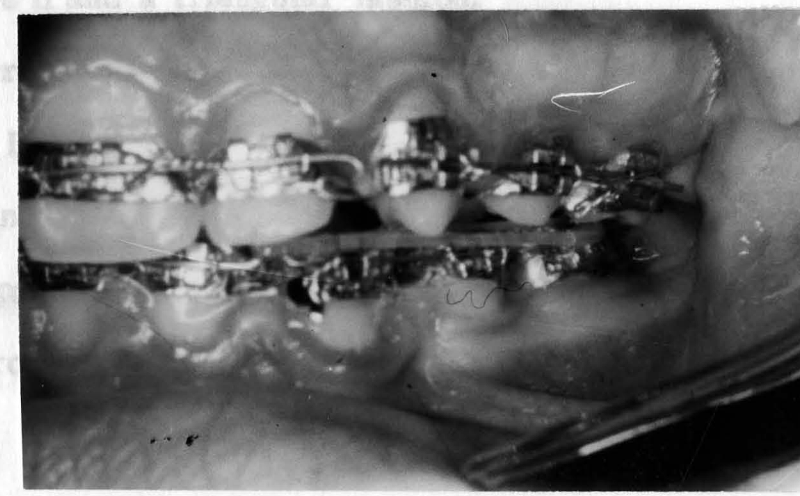
Angle Classification: Class II Division 1



Subject #13 (A.S.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.





Subject #13 (A.S.) Age 13

Class II Division 1 (Angle)

Treatment:

A. Extraction of the four first premolars.

B. Appliance design. (See Methods and Materials page 70.)

The maxillary archwire was a horizontal hook consolidation archwire with coil springs and sliding hooks to the upper canines.

The mandibular archwire was a horizontal hook consolidation archwire.

The elastics were worn in three ways as described in Methods and Materials (page 81). The elastics used were intramaxillary in the mandibular arch, and between the arches, elastics were worn in a Class II and a triangular fashion.

Evaluation of the Characteristics of the Myograms.

Bursts: Experiments I and II showed very few vursts while Experiments III to VI showed an increase to a range of from two to five bursts. The number of bursts drops in Experiment VII to one to four bursts.

Amplitude: Varied from moderate to maximum throughout all experiments.

Duration: Moderate throughout all experiments, except for a decrease to minimal in Experiments II and III.

Noding: Moderate in Experiments I, V, and VII and maximum in all other experiments.

Sustained low amplitude: Absent in Experiments I, III and IV, moderate in Experiment II, and moderate in the left masseter only Experiments V and VI. Minimum in both masseters and the left posterior temporal in Experiment VII.

Rate of onset: Remained moderate throughout all experiments.

Rate of ending: Moderate for the first five experiments, but increasing to maximum in Experiment VI and decreasing back to moderate in Experiment VII.

Interim activity: At first maximum, then became moderate in Experiments II and III, and then decreased to minimum in the remaining Experiments except for Experiment VII where it became moderate.

Initiation of chewing activity: The masseters, at first the predominant muscles in initiating activity, became less active in this role until Experiment V, when they initiated activity only once. In

Experiment VI there was an increase in their role as initiators of activity. The temporals, at first almost inactive in initiating activity, gradually became more active in this role, and in Experiment VI initiated activity almost one-half of the time. Synchronous onset of activity became more predominant from Experiment I to Experiment V when it was the most important group initiating chewing activity. The synchrony then decreased in frequency of occurrence in Experiment VI, but increased to three-fourths of the time in Experiment VII.

Conclusion:

This subject displayed reasonably good muscular adaptation to the orthodontic procedures.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 13 A. S.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-3	XXX	XX	XX	O	XX	XX	XXX
II	3	XX	X	XXX	XX	XX	XX	XX
III	2-5	XXX	X	XXX	O	XX	XX	XX
IV	2-5	XXX	XX	XXX	O	XX	XX	X
V	2-5	XX	XX	XX	XX-MASS.	XX	XX	X
VI	3-5	XX	XX	XXX	XX-MASS.	XX	XXX	X
VII	1-4	XXX	XX	X-XX	X	XX	X-XX	XXX

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

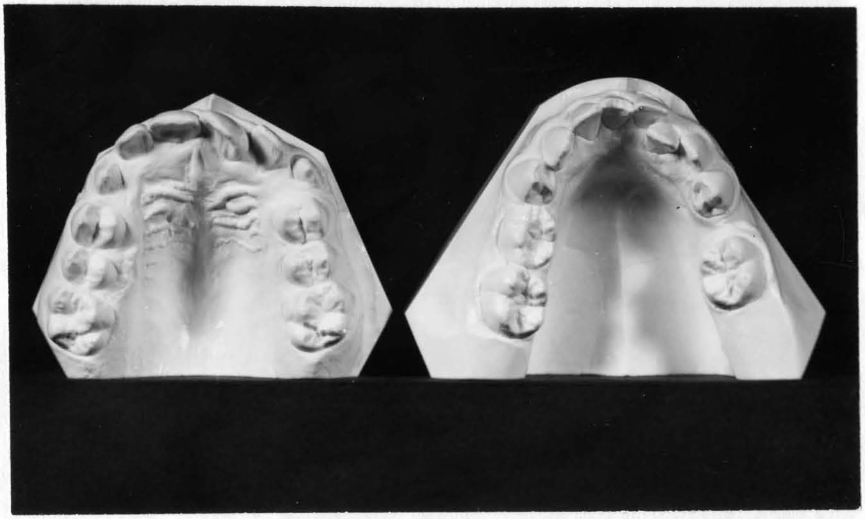
SUBJECT NUMBER: 13. A. S.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	6	3	2	3	1	3	3
Masseter and middle temporal first	1	3	1	1	0	0	0
Masseter and posterior temporal first	1	0	1	0	0	0	0
Middle and posterior temporal first	1	1	1	2	3	4	1
Middle temporal first	0	0	1	0	0	1	0
Posterior temporal first	0	0	0	0	0	0	0
All together (Synchrony)	3	5	6	6	8	4	8
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #14 (D. T.) Age 15

Original Malocclusion

Angle Classification: Class I, Pseudo Class III



Subject #14 (D. T.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.

Subject #14 (D. T.) Age 15

Class I, Pseudo Class III (Angle)

Treatment:

A. No teeth were extracted.

B. Appliance design. (See Methods and Materials page 82.)

At the time electromyographic recordings were taken for Experiment VII, this subject already had the active appliance removed and was using a rubber finishing appliance for functional retention.

Evaluation of the Characteristics of the Myograms.

Bursts: Remained relatively the same (two to six) throughout the first six experiments but dropped in Experiment VII.

Amplitude: Ranged from moderate to minimum throughout the first six experiments and then became maximum in Experiment VII.

Duration: Remained moderate throughout all experiments.

Noding: Remained maximum in the first six experiments and then dropped to minimum in Experiment VII.

Sustained low amplitude: Occurred in all experiments except Experiment IV.

Rate of onset: Moderate throughout all experiments.

Rate of ending: Moderate throughout all experiments.

Interim activity: Minimum in all experiments except Experiments III, and IV, when it was moderate.

Initiation of chewing activity: The masseters, which at first initiated activity one-half of the time, became less active in the role of initiating activity until, in Experiment VI, they only initiated activity once out of twelve times and not at all in Experiment VII. Synchrony of all muscles, on the other hand, which at first played a very minor role in initiation of activity became more predominant and in Experiment VI initiated activity one-half of the time and did so again in Experiment VII. The temporals, also almost inactive in initiating activity at first, became more important in later experiments. In Experiment VI they were active in the onset of activity almost one-half of the time and exactly one-half of the time in Experiment VII.

Conclusion:

This subject adapted well to the orthodontic procedures.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 14 D. T.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-6	xx	xx	xxx	x	xx	xx	x
II	2-4	x	xx	xx	x	xx	xx	x
III	3-5	xx	xx	xxx	x	xx	xx	x
IV	3-6	xx	xx-xxx	xxx	0	xx	xx	xx
V	2-6	x	xx	xxx	x	xx	xx	x
VI	2-5	x	xx	xxx	x-mass.	xx	xx	x
VII	1-3	xxx	xx-xxx	x-xx	0	x-xx	x-xx	x-xx

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

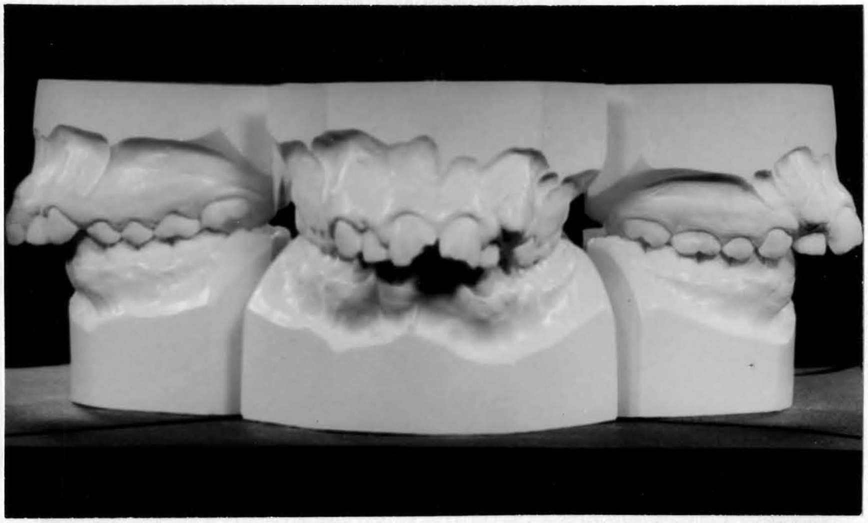
SUBJECT NUMBER: 14. D. T.

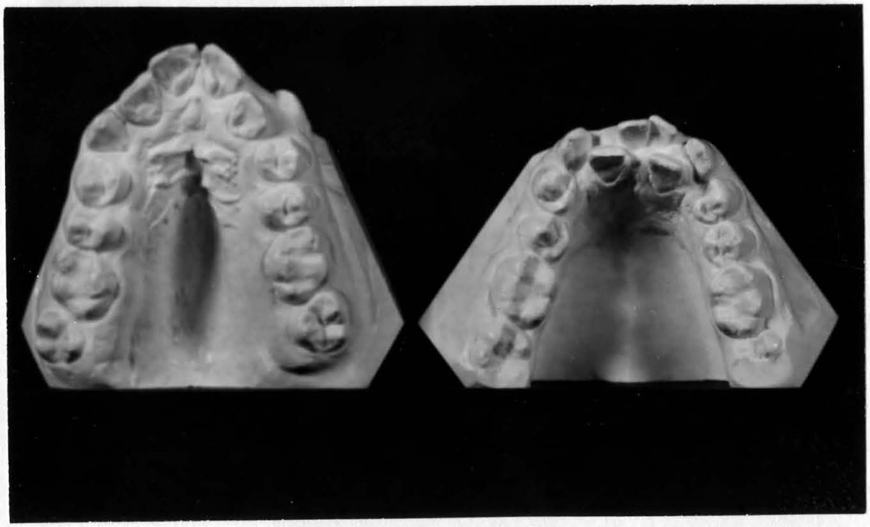
EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	6	3	3	0	3	1	0
Masseter and middle temporal first	0	1	0	0	0	0	0
Masseter and posterior temporal first	1	0	1	0	0	0	0
Middle and posterior temporal first	2	2	3	2	6	4	6
Middle temporal first	1	0	0	0	0	0	0
Posterior temporal first	0	1	1	5	0	1	0
All together (Synchrony)	2	5	4	5	3	6	6
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #15 (J. V.) Age 16

Original Malocclusion

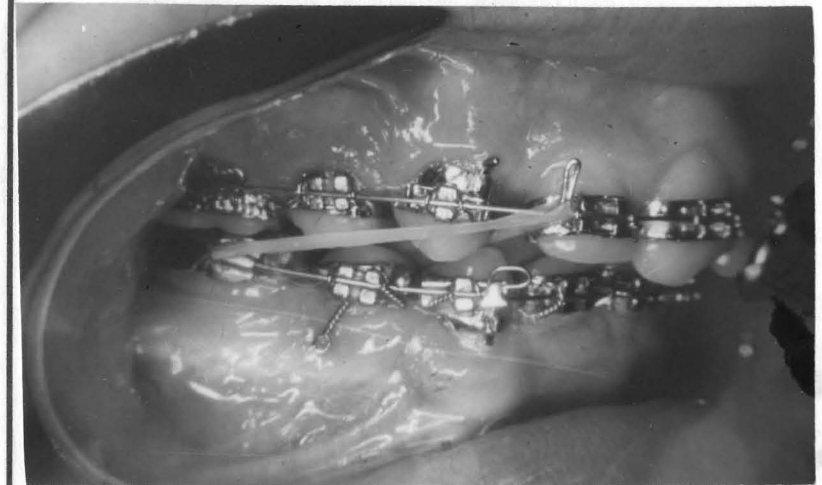
Angle Classification: Class II Division 1

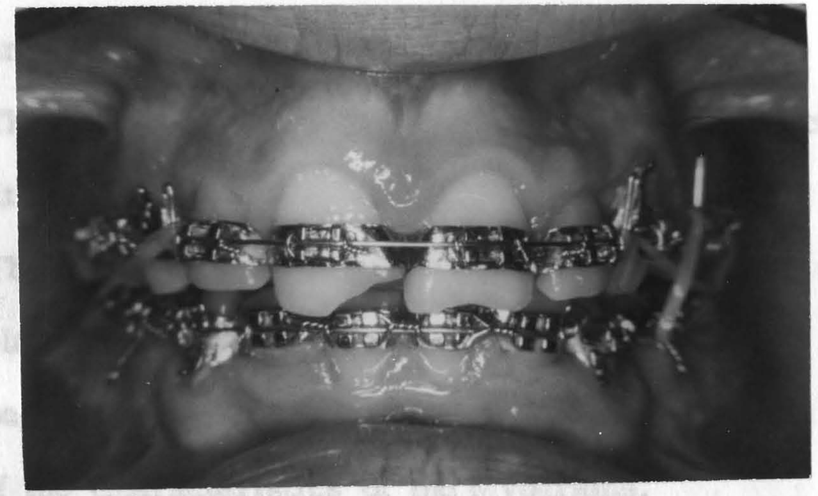


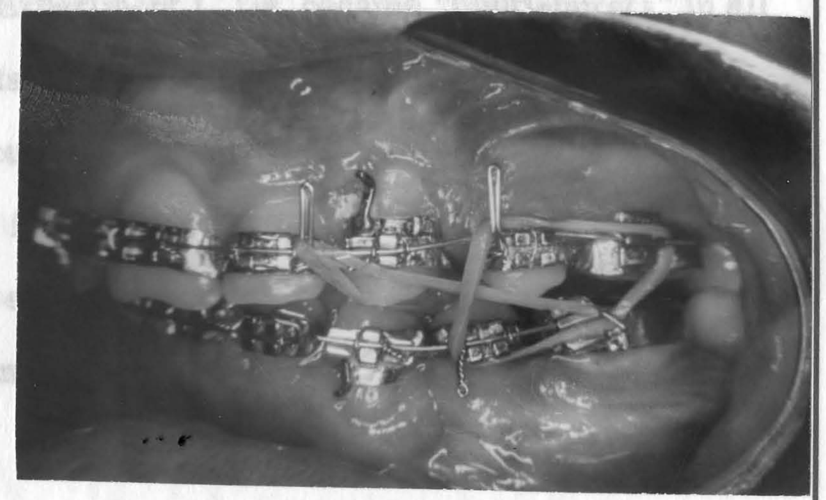


Subject #15 (J. V.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.







Subject #15 (J. V.) Age 16

Class II Division 1 (Angle)

Treatment:

A. Extraction of the four first premolars.

B. Appliance design. (See Methods and Materials page 70.)

The maxillary archwire was a vertical hook consolidation archwire.

The mandibular archwire was a horizontal hook consolidation archwire.

The elastics used were intermaxillary Class II's and an elastic worn in a triangular fashion (See Methods and Materials page 81.)

Evaluation of the Characteristics of the Myograms.

Bursts: Moderate in Experiment I, but became "multi-bursts" in all of the following experiments except for Experiment VII which had a reduction to one to three bursts.

Amplitude: Moderate in Experiments I and II and then became maximum in the remaining experiments.

Duration: Moderate in Experiments I and II, maximum in Experiments III and IV, and then between moderate and maximum in Experiments V, VI and VII.

Noding: Moderate in Experiments I and II, then became maximum throughout the remaining experiments until Experiment VII where it dropped to minimum to moderate.

Sustained low amplitude: Minimum throughout all experiments.

Rate of onset: Moderate for the first five experiments and then became maximum in Experiment VI and then in Experiment VII returned to minimum to moderate.

Rate of ending: Moderate to Experiment VII then it becomes minimum.

Interim activity: Minimum to moderate throughout first six experiments and then in Experiment VII it becomes maximum.

Initiation of chewing activity: Synchrony of all muscles, which initiated activity one-half of the time in the first two experiments, became more predominant in Experiments IV and V, when it initiated two-thirds of the chewing strokes. There was a marked decrease in synchronous initiation of the chewing stroke in Experiment VI and a marked increase in Experiment VII where it initiated the chewing stroke ten out of the possible twelve times. The masseters, at first somewhat active in initiating activity, failed to initiate activity in Experiments IV and V and initiated activity only once in Experiment VI and twice in Experiment VII. The middle and posterior temporals as a group showed increased importance in initiating activity, doing so in one-half of the chewing strokes in Experiment VI, but not at all in Experiment VII.

Conclusion:

This subject exhibited some difficulty in adapting to the orthodontic procedures but finally did so at the time of Experiment VII, showing less inhibition during mastication and more occurrence of synchronous initiation of chewing activity.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 15 J. V.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	1-6	XX	XX	XX	X-POST. TEMP.	XX	XX	X
II	4-8	XX	XXX	XXX	X	XX	XX	XX
III	4-8	XX	XXX	XXX	X-POST. TEMP.	XX	XX	X
IV	4-8	XXX	XXX	XXX	X-POST. TEMP.	XX	XX	X-XX
V	4-8	XX-XXX	XXX	XXX	X-MASS.	XX	XX	X-XX
VI	4-8	XXX	XXX	XXX	X-MASS.	XXX	XX	X-XX
VII	1-3	XXX	XXX	X-XX	X	X-XX	X-XX	XXX

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

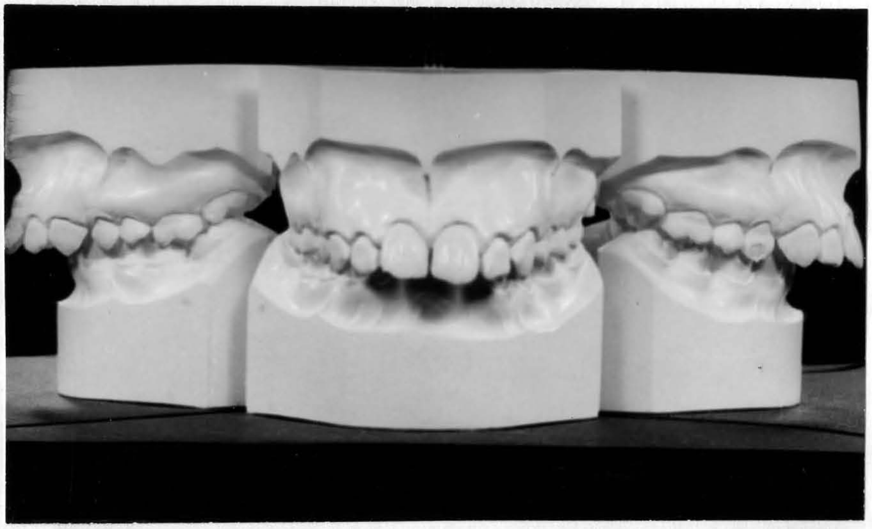
SUBJECT NUMBER: 15. J. V.

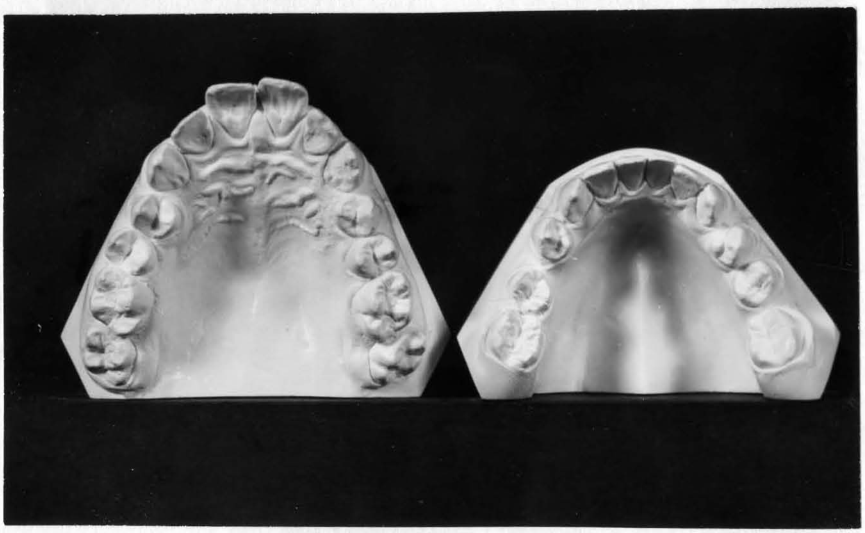
EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	3	1	3	0	0	1	2
Masseter and middle temporal first	0	1	1	1	0	1	0
Masseter and posterior temporal first	0	0	0	0	0	0	0
Middle and posterior temporal first	1	4	3	1	4	6	0
Middle temporal first	1	0	1	0	0	0	0
Posterior temporal first	1	0	0	0	0	0	0
All together (Synchrony)	6	6	4	10	8	4	10
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

Subject #16 (J. W.) Age 14

Original Malocclusion

Angle Classification: Class II Division 1





Subject #16 (J. W.)

TREATMENT STAGE AT THE TIME ELECTROMYOGRAPHIC RECORDINGS WERE TAKEN FOR EXPERIMENT VII.

Subject #16 (J.W.) Age 14

Class II Division 1 (Angle)

Treatment:

A. Extraction of the maxillary first premolars (lower first permanent molars missing).

B. Appliance design. (See Methods and Materials page 72 and 75.)
The maxillary archwire was a rectangular torquing archwire.
The mandibular archwire was a straight (horizontal) ideal archwire with second order bends.
The elastics were worn as described in Methods and Materials (page 81), in a Class II and a triangular fashion between the two arches.

Evaluation of the Characteristics of the Myograms.

Bursts: Remained in the same range (two to six) throughout all experiments.

Amplitude: Remained minimum until Experiment IV where it increased to moderate to maximum.

Duration: Minimum at first, increased to maximum in Experiment IV and then decreased to moderate in Experiment V, VI and VII.

Noding: Minimum in Experiments I and IV and moderate in all other experiments.

Sustained low amplitude: Showed moderate to maximum activity in Experiments I through V. In Experiments VI and VII the sustained low amplitude became minimum.

Rate of onset: Minimum until Experiment VII where it became moderate.

Rate of ending: Minimum for the first four experiments and then became slightly increased in Experiments V, VI and VII.

Interim activity: Remained minimum throughout all experiments except for and increase to moderate in Experiment VI and also Experiment VII.

Initiation of chewing activity: The temporals were predominant in initiating the chewing stroke throughout the first five experiments. There was some synchronous initiation of activity at first, but this was reduced in Experiment IV and V. In Experiment VI, synchrony of all muscles in initiating the chewing stroke occurred in nearly all of the chewing exercises. In Experiment VII initiation of chewing activity was accomplished by almost all muscles groups mainly the middle and posterior temporal.

Conclusion:

This subject's muscular behavior adapted well to the orthodontic procedures until Experiment VII where the electromyographic pattern of chewing became worse than it had been previously, exhibiting much more inhibition during mastication at this time, probably due to the fact that this subject was being treated to a full Class II (distocclusion) molar relation.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 16 J. W.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	1-6	XX	XX	XX	X-POST. TEMP.	XX	XX	X
II	2-8	XX	XX	XX	X	XX	XX	X
III	2-8	XX	XXX	XXX	X-POST. TEMP.	XX	XX	X
IV	4-7	XXX	XXX	XXX	X-POST. TEMP.	XX	XX	X-XX
V	4-7	XXX	XX-XXX	XXX	X-MASS.	XX	XX	X-XX
VI	2-7	XXX	XX-XXX	XXX	X-MASS.	XXX	XX	X-XX
VII	2-7	XX-XXX	XX	XX-XXX	X	XX	XX	X-XX

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 16. J. W.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII
Masseter first	1	2	0	1	0	1	1
Masseter and middle temporal first	1	0	1	0	1	0	0
Masseter and posterior temporal first	1	0	0	0	0	0	0
Middle and posterior temporal first	3	2	5	9	4	1	5
Middle temporal first	0	0	0	0	0	0	2
Posterior temporal first	3	4	0	0	5	1	2
All together (Synchrony)	3	4	6	2	2	9	2
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12

General Conclusion:

In most cases the electromyographic pattern of muscular behavior exhibited more inhibition or noding and less synchrony in initiation of chewing activity from the original malocclusion through the placement of the first archwires. The muscular behavior, regarding the electromyographic qualities studied, improved during anchorage preparation, then showed less harmony at the completion of anchorage preparation and improved again during the final stages of orthodontic treatment.

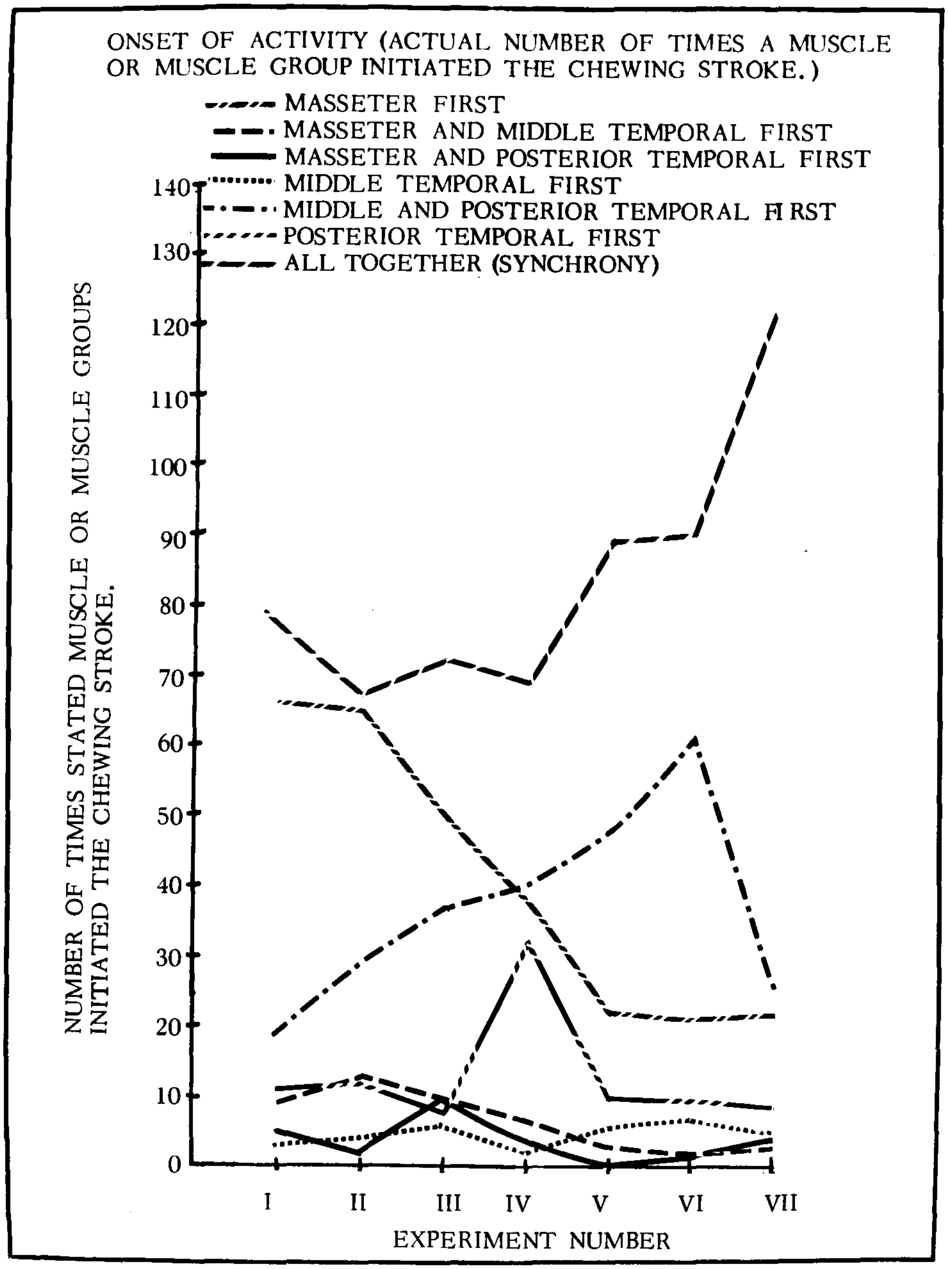
C. Part II

The onset of electromyographic activity for each of the muscles or muscle groups in each of the first three chewing cycles of each chewing exercise (considering the ipsilateral side only) for each individual subject in this experiment, Experiment VII (During the Final Stages of Orthodontic Treatment.), was tabulated in chart form. Then the totals for the individual subjects were summed and a chart was made showing the number of times each muscle or muscle group initiated chewing activity in Experiment VII. These data were then added to the similar data from Experiments I through VI and appear in Part II of the "FINDINGS" as Chart II. This chart was also illustrated graphically as Graph I in Part II of the "FINDINGS". The tabulations appearing in the chart and the graph were done using all seven possible combinations of the muscle and muscle groups studied in this experiment as follows: masseter first, masseter and middle temporal first, masseter and posterior temporal first, middle and posterior temporal first, middle temporal first, posterior temporal first, and all together (synchrony).

The object of this method of study being to observe any general trends that may have occurred in the division of labor between the

CHART 2. COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS FOR ALL SUBJECTS.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	66	65	50	38	22	21	22	19
Masseter and middle temporal first	9	13	10	7	3	2	3	5
Masseter and posterior temporal first	5	2	10	4	0	1	5	4
Middle and posterior temporal first	19	29	37	40	48	61	25	12
Middle temporal first	3	4	6	2	6	7	5	5
Posterior temporal first	11	12	7	32	10	10	9	11
All together (Synchrony)	79	67	72	69	89	90	123	136
TOTAL NUMBER OF CHEWING STROKES	192	192	192	192	192	192	192	192


ONSET OF ACTIVITY (ACTUAL NUMBER OF TIMES A MUSCLE OR MUSCLE GROUP INITIATED THE CHEWING STROKE.)
MASSETER FIRST
MASSETER AND MIDDLE TEMPORAL FIRST
MASSETER AND POSTERIOR TEMPORAL FIRST
MIDDLE TEMPORAL FIRST
MIDDLE AND POSTERIOR TEMPORAL FIRST
POSTERIOR TEMPORAL FIRST
ALL TOGETHER (SYNCHRONY)
NUMBER OF TIMES STATED MUSCLE OR MUSCLE GROUPS INITIATED THE CHEWING STROKE.
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
I
II
III
IV
V
VI
VII
EXPERIMENT NUMBER

muscles being studied, from the beginning of orthodontic treatment through the final stages of treatment.

Of the various combinations of muscles and muscle groups being studied for the initiation of chewing activity, the combination to initiate the chewing cycle most often, throughout all experiments thus far in this study, was the combination of the masseters and middle and posterior temporals acting concurrently. Out of a possible 192 times this combination of muscles initiated the chewing activity 79 times in Experiment I (The Original Malocclusion). Initiation of activity on the part of these muscles as a group, decreased slightly in Experiment II (One Day After the Placement of Separating Wires Between the Teeth) and stayed fairly level, with only slight up and down fluctuations through Experiments III (One Week After the Placement of Separating Wires Between the Teeth) and IV (One Week After the Placement of the First Archwires), but began to increase in Experiment V (During Anchorage Preparation), where they initiated chewing activity 89 out of 192 times, and continued to increase through Experiment VII (During Final Stages of Treatment), where they initiated activity 123 times out of the possible 192.

The second most frequently occurring muscles or muscle groups to initiate the chewing cycle in the original malocclusion were the masseters. These muscles showed their greatest activity in initiating the chewing activity in Experiment I (The Original Malocclusion), where they initiated the chewing cycle sixty-six times out of a possible 192. From there on, the activity on the part of the masseters progressively decreases and in Experiment VII (During the Final Stages of Treatment) they initiated the chewing cycle only twenty-two times out of the possible 192. It is interesting to note, however, that although there is a decrease in the number of times the masseters initiated chewing activity from the original malocclusion, to one week after the placement of the first arch-wires, there seems to be a leveling of the initial rapid decrease, and the number of times the masseters initiated chewing activity from during anchorage preparation on, remained fairly constant being twenty-two, twenty-one and twenty-two times out of the possible 192 for Experiments V, VI, and VII, respectively.

The combination of the middle and posterior temporal muscles, acting together in initiating the chewing cycle, was the third most active initiator in the original malocclusion, initiating activity nineteen times out of 192 times. This combination showed a steady increase from Experiment I (Original Malocclusion) through Experiment VI (After Completion of Anchorage Preparation), where they initiated chewing activity sixty-one times out of a possible 192, but in Experiment VII (During Final Stages of Treatment) showed a rapid drop to twenty-five times out of a possible 192.

The posterior temporal showed little variation in the number of times it initiated the chewing activity except during Experiment IV (One Week After Placement of the First Archwires), when it initiated the chewing activity approximately three times more often than during any other phase of treatment.

The remainder of the muscles or muscle combinations studied in this experiment stayed relatively constant in the number of times they initiated chewing activity throughout the entire study.

Comparing the activity of the middle and posterior temporals acting together, with that of the masseters, and concurrent activity of all three muscles, it can be seen that initiation on the part of the middle and posterior temporals steadily increases, while initiation on the part of the masseters steadily decreases until Experiment IV (One Week After the Placement of the First Archwires) where the middle and posterior temporals initiate chewing activity only slightly more than the masseters. After this point, initiation of chewing activity seems to be largely a function of the middle and posterior temporals acting together, or of the three pairs of muscles acting concurrently, until Experiment VII (During Final Stages of Treatment) where initiation on the part of the middle and posterior temporals drops suddenly (twenty-five out of a possible 192 times) and concurrent initiation of the chewing activity by all three pairs of muscles acting synchronously becomes dominant.

As shown in Experiments I through VI in Part V of this study, the trend seemed to indicate a decreasing participation on the part of the masseter muscles and an increasing participation on the part of the combination of the middle and posterior temporal muscles. But in Experiment VII (During the Final Stages of Orthodontic Treatment) the trend changes and, although initiation of the chewing cycle on the part of the masseters continues to decrease, so does initiation of the chewing cycle on the part of the middle and posterior temporals. It is at this point that the concurrent activity of all three pairs of muscles take over the initiation of chewing activity.

D. Part III

The object of expressing the chewing stroke or biting stroke as a percentage of the chewing cycle in each experiment for all sixteen subjects was to see what effect, if any, the different stages of orthodontic treatment had on the length of the chewing stroke or biting stroke and to see what the trend was as orthodontic treatment progressed. (A chewing stroke or biting stroke was considered to be that portion of the chewing cycle that began with the onset of electrical activity and ended with the cessation of electrical activity as detected electromyographically.)

In order to do this, a statistical analysis was used that would be applicable in determining if there were a statistically significant difference between the various stages of treatment that distinguished these seven experiments in this study. In addition to this, the actual percentage values were counted and their frequency of occurrences were tabulated and made into a separate histogram for each experiment. These histograms were then compared to ascertain the trend.

The Chi Square Test was used to compare these data of the length of the chewing stroke from experiment to experiment. A highly significant difference was found to exist between the seven experiments at the .001

level of significance with thirty-six degrees of freedom. This showed that there was a significant change in the distribution of the durations of the chewing strokes or biting strokes expressed as a percentage of the chewing cycle between the seven experiments.

Again using the Chi Square Test, Experiment VII (During the Final Stages of Orthodontic Treatment) was compared against Experiment I (Original Malocclusion) and the two were found to be significantly different at the .001 level of significance with six degrees of freedom. This would mean that the distribution of the durations of the chewing strokes or biting strokes in Experiments I and VII were in no way alike.

Another comparison was made between Experiment VII and Experiment VI (After Completion of Anchorage Preparation) and a significant difference at the .001 level of significance with six degrees of freedom was found to exist. This would mean that the distribution of the durations of the chewing strokes or biting strokes in these two experiments, although different, were not nearly as different as the distributions of the durations of the chewing strokes or biting strokes between Experiments I and VII.

From this analysis it can be seen that there is no similarity in

TABLE OF CHI SQUARE VALUES FOR THE FREQUENCY OF OCCURRENCES OF PERCENTAGES WITHIN CLASS INTERVALS

EXP. NO.	I	II	III	IV	V	VI	VII
CLASS INTERVAL							
0-34.9%	9.08	2.56	2.83	1.19	.02	17.67	16.08
35-44.9%	6.03	17.45	3.38	.78	.14	14.59	2.20
45-54.9%	.58	.03	6.78	1.62	.61	1.28	.18
55-64.9%	12.09	6.79	18.01	2.11	.01	1.66	5.36
65-74.9%	.32	3.24	3.38	.80	2.44	3.05	3.05
75-84.9%	8.56	.23	7.69	.13	1.42	9.22	.59
85-100%	2.60	5.24	.03	66.80	1.06	6.17	5.73
TOTAL	151.05	48.00	46.62	76.00	8.65	46.17	36.71

TOTAL $CHI^2 = 278.57$***
WITH 36 DEGREES OF FREEDOM

THE ASTERISKS CORRESPOND TO THE LEVEL OF SIGNIFICANCE AS FOLLOWS: * TO 5%; ** TO 1%; *** TO 0.1%.

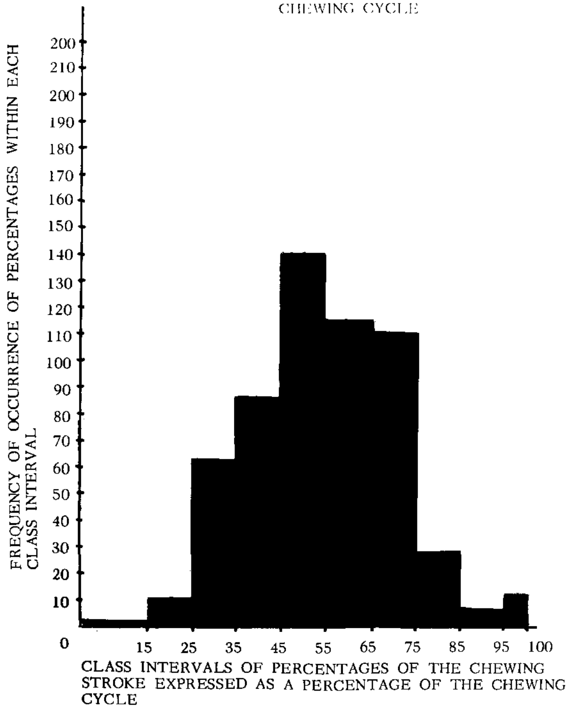
the distribution of the durations of the chewing strokes or biting strokes expressed as a percentage of the chewing cycle in these phases of orthodontic treatment and it further emphasizes that the duration of the chewing stroke or biting stroke expressed as a percentage of the chewing cycle changes during orthodontic treatment.

To facilitate a method of grouping the data, percentage intervals were arbitrarily designated and were called class intervals. These were as follows: 0-14.9%, 15-24.9%, 25-34.9%, 35-44.9%, 45-54.9%, 55-64.9%, 65-74.9%, 75-84.9%, 85-94.9%, and 95-100%.

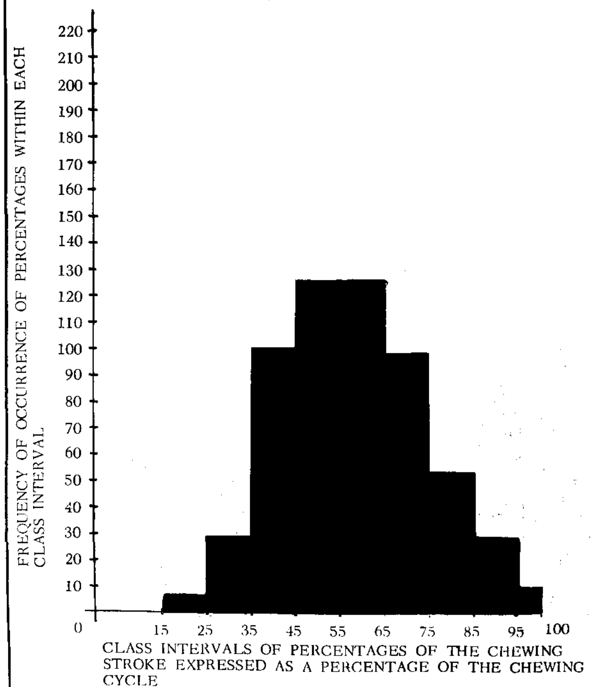
When the duration of the chewing stroke or biting stroke expressed as a percentage of the chewing cycle fell within any of the above mentioned groupings it was plotted as part of that group. The frequency of occurrence of the various percentages were then plotted within each class interval. A separate histogram was made for each Experiment and these are shown as Graph II in Part III of the "FINDINGS".

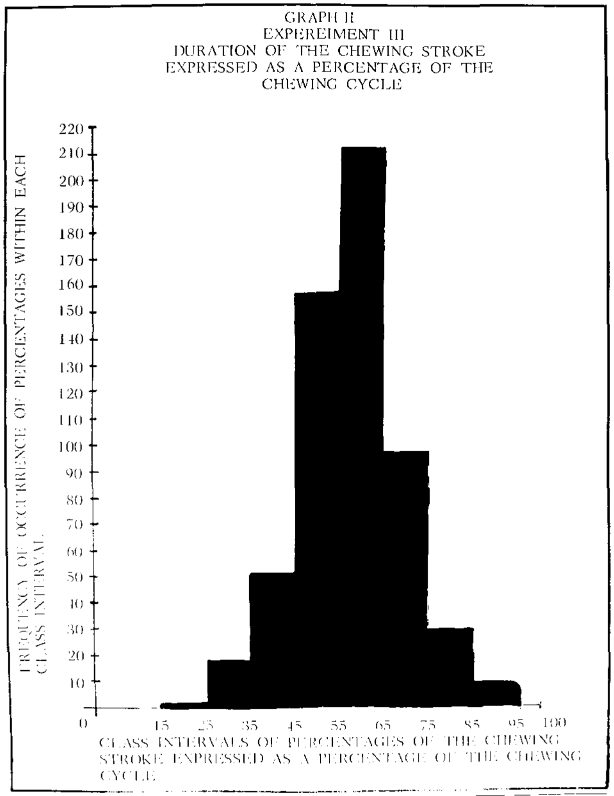
In comparing these histograms it was noted that as orthodontic treatment progressed the frequency of occurrence of the smaller percentages (0-25%) decreased, while those of the class intervals between 45%-65% showed an increase. The remaining class intervals on either side of the 45%-65% range varied from Experiment to Experiment, but remained within the same range. They showed no upward or downward trend.

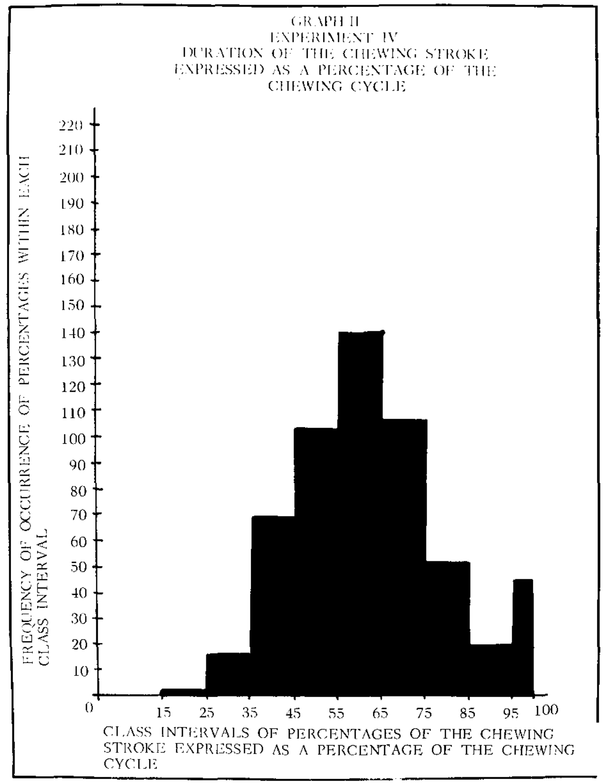
GRAPH II
EXPERIMENT I
DURATION OF THE CHEWING STROKE
EXPRESSED AS A PERCENTAGE OF THE
CHEWING CYCLE



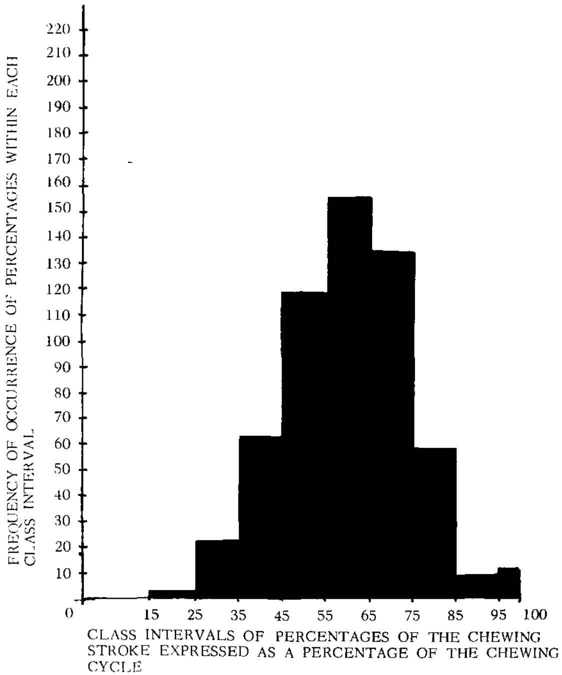
GRAPH II
EXPERIMENT II
DURATION OF THE CHEWING STROKE
EXPRESSED AS A PERCENTAGE OF THE
CHEWING CYCLE



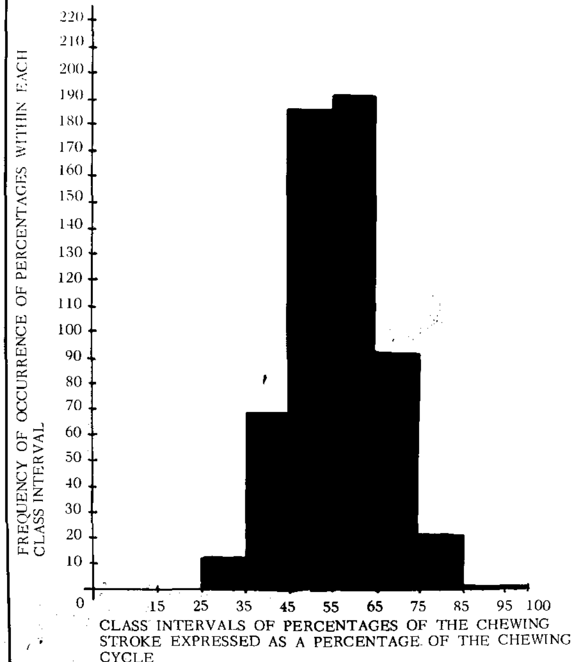

GRAPH II
EXPEREIMENT III
DURATION OF THE CHEWING STROKE
EXPRESSED AS A PERCENTAGE OF THE
CHEWING CYCLE
FREQUENCY OF OCCURRENCE OF PERCENTAGES WITHIN EACH CLASS INTERVAL
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
15 25 35 45 55 65 75 85 95 100
CLASS INTERVALS OF PERCENTAGES OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE


GRAPH II
EXPERIMENT IV
DURATION OF THE CHEWING STROKE
EXPRESSED AS A PERCENTAGE OF THE
CHEWING CYCLE
FREQUENCY OF OCCURRENCE OF PERCENTAGES WITHIN EACH CLASS INTERVAL
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
15 25 35 45 55 65 75 85 95 100
CLASS INTERVALS OF PERCENTAGES OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE

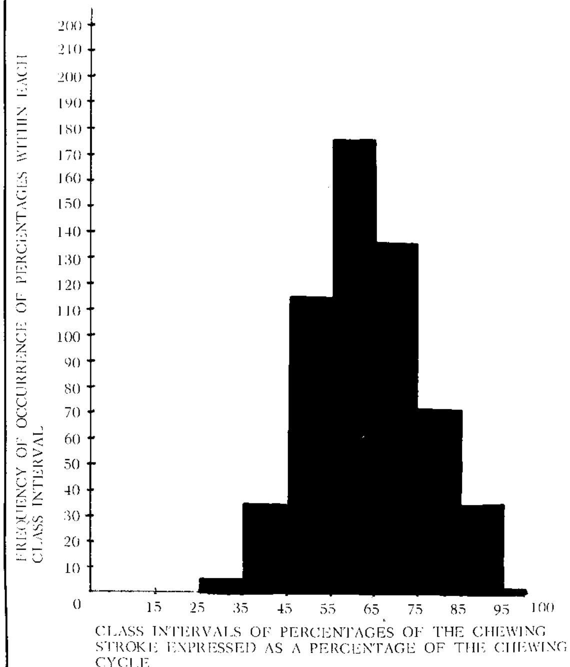
GRAPH II
EXPERIMENT V
DURATION OF THE CHEWING STROKE
EXPRESSED AS A PERCENTAGE OF THE
CHEWING CYCLE



GRAPH II
EXPERIMENT VI
DURATION OF THE CHEWING STROKE
EXPRESSED AS A PERCENTAGE OF THE
CHEWING STROKE



GRAPH II
EXPERIMENT VII
DURATION OF THE CHEWING STROKE
EXPRESSED AS A PERCENTAGE OF THE
CHEWING STROKE



E. Part IV

The object of analyzing the number of bursts in a chewing stroke or biting stroke was to ascertain if there were a statistically significant difference between the amount of inhibition occurring in the temporal and masseter muscles during the chewing strokes or biting strokes of those subjects still wearing appliances and those who already had the appliances removed during the time electromyographic recordings were taken for this part of the study (Experiment VII - During the Final Stages of Orthodontic Treatment.) Fleming (1961), in Part V (After the Completion of Anchorage Preparation) of this longitudinal study, concluded that the number of bursts of electrical activity during a chewing stroke derived from the muscles studied, is a reasonably good indicator of the number of times inhibition had taken place during the chewing stroke, in the temporal and masseter muscles. Although Fleming did not actually prove this but deduced this, it will be used as a basis for this method of analysis for reasons that will be explained in the "DISCUSSION".

The number of bursts in a chewing stroke or biting stroke for each of the first three chewing strokes or biting strokes of the four chewing exercises for all sixteen subjects were counted and a random sample of one-third of the chewing strokes or biting strokes for each subject were selected using a table of random numbers. These random samples were used in this analysis. See "METHODS AND MATERIALS" page 94.

Since the values obtained were counts and do not follow a normal distribution, they were transformed (the transformation used was the square root of the observation plus one) and an analysis of variance performed on the transformed data.

There were several main effects involved and it was necessary to set up the data sheet so that the variance for these main effects could be calculated. (A sample data sheet showing a portion of the data appears in "METHODS AND MATERIALS" on page 96.) It was also necessary to include all known variance sources in the analysis of variance table, to reduce the size of the experimental error (residue) by assigning all possible degrees of freedom to the known variance sources.

The main effects listed were as follows: Between appliances (between those subjects still wearing appliances and those with the appliances already removed), between sides (right and left), between muscles (posterior temporal, middle temporal, and masseter), and between subjects within groups (the groups were those subjects with and those subject without appliances). In addition, several of the most likely interactions were listed. The remaining variance sources were: between duplicates (duplicate exercises were used to minimize experimental error) and residue (experimental error).

Since the two main groups (those subjects with appliances and those subjects without appliances) each had a different number of subjects in them, the sums of square for each group had to be calculated separately and then summed to arrive at the sum of squares for "between subjects within groups". (Four subjects had appliances already removed and twelve were still wearing appliances.)

The Analysis of Variance Table with all the calculations and F values (variance ratios) appears on page 214.

In comparing the mean squares, the mean square or variance between duplicates was compared against that of the residue, and since no significant F value was obtained neither value could be used alone as an error term against which the main effects and interactions could be tested for significance so the two values were summed and the combined value used as an error term, against which all interactions and main effects were tested for significance.

ANALYSIS OF VARIANCE TABLE

SOURCES OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARE	F
APPLIANCES	1	.96	.96	11.03***
SIDES	1	.18	.18	2.07
MUSCLES	2	.31	.16	1.84
SUBJECTS WITHIN APPLIANCES	14	10.63	.76	8.74***
A x S	1	.09	.09	1.03
A x M	2	.03	.015	.172
S x M	2	.06	.03	.345
RESIDUE	72	7.58	$\frac{1462}{168}$ = .087	
DUPLICATES	96	7.04		
TOTAL	191	26.88		

THE ASTERISKS CORRESPOND TO THE LEVEL OF SIGNIFICANCE AS FOLLOWS: * TO 5%; **1%; *** TO 0.1%.

Only two significant F values were obtained. Between subjects within groups showed a very significant difference beyond the .001 level with fourteen degrees of freedom in the numerator and 168 degrees of freedom in the denominator. This was to be expected since each group was heterogenous due to the different malocclusions present within each group and the different treatment stages.

The other significant difference was found to be between appliances (those subjects with appliances and those subjects without appliances). Here again, a very significant difference existed beyond the .001 level with one degree of freedom in the numerator and 168 degrees of freedom in the denominator. This would mean that there was a very significant difference between those subjects wearing appliances and those not wearing appliances in regard to the number of times inhibition took place in the muscles being studied during the chewing strokes or biting strokes, the least number of bursts per chewing stroke or biting stroke being in the group that already had the appliances removed.

CHAPTER IV

DISCUSSION

A. General Considerations

In the orthodontic literature much emphasis has been placed on the ideal placement of teeth in positions which would not only be esthetically pleasing, but which would be in harmony with the temporomandibular joints and the muscles as well, yet very little has been done to show what is happening to the muscles that move the mandible during mastication from the time of the original malocclusion until all orthodontic and retentive appliances have been discontinued. This is most important because it is the function of the occlusion, which is controlled by the musculature, that will determine the final position of the teeth after growth is completed.

Basically then, this study was done to determine what effect, if any, the change in sensory input due to the change in the position of the teeth during orthodontic treatment, had on the motor output to the temporal and masseter muscles during mastication. It is hoped that, through a better understanding of what is happening to the function of the muscles governing mandibular movement, before, during, and after orthodontic treatment, the orthodontist can gain more insight into the problem of the stability of his results and use a more scientific, rathern than an empirical ideal to which he may treat his cases.

Since mandibular movements, and therefore mastication, are controlled by the neuromuscular mechanism, an understanding of the physiology of this mechanism is important.

It is a well known fact that any force applied to the teeth, no matter how slight, is transmitted to the periodontal ligament. The highly arborized nerve endings in the periodontal ligament, as described by Lewinsky and Stewart (1937), Dependorf (1913), Van der Sprenkel (1936), Kadanoff (1927), Bernick and Rapp (1957), are the proprioceptors of the periodontal ligament and are confined to the peripheral part of the ligament. These specialized end-organs are myelinated. The sensory receptors for pain, located in the periodontal ligament, are fine nerve fibers which pass to the deeper part of the periodontal ligament and break up into fine arborization without terminal organs. These afferent nerve fibers which conduct pain impulses from the periodontal ligament are principally unmyelinated, although there are a few small myelinated fibers also present.

The proprioceptors located in the substance of the muscles are the neuromuscular spindles, which consist of small groups of attenuated muscle fibers (intrafusal muscle fibers) around which the endings of the sensory nerve fibers are coiled in a corkscrew fashion. In addition to these, there are neurotendinous organs or organs of Golgi, located at the junction of muscles and tendons and aponeuroses of muscles. These consists of small bundles of collagenous fibers.

The special proprioceptive nerve endings located in the capsule and ligaments of the temporomandibular articulation are the Pacinian corpuscles, which are much like the Golgi tendon organs, both in function and structure.

The afferent fibers of the spinal nucleus of the trigeminal nerve mediate pain impulses from the periodontal ligament. The pain impulses are conducted over these fibers to the spinal nucleus of the trigeminal nerve, which extends from the pons down to the upper-most cervical levels of the spinal cord. These impulses then ascend from the spinal cord level and are relayed to the cerebral cortex where they are correlated. The motor cortex is then stimulated, and the musculature is activated through an efferent two-neuron pathway.

The importance of this being that when pain enters into the picture during mastication the control of the mandibular musculature is on a more conscious level rather than being reflex in nature.

The afferent proprioceptive impulses arising from the periodontal ligament and muscles of mastication travel along special pathways to the mesencephalic root of the trigeminal nerve. Here these impulses can follow one of two pathways. The first pathway is to form a reflex arc with the motor ganglion cells of the trigeminal motor nucleus, the two-neuron reflex arc of the masticatory muscles, as described by Corbin and Harrison (1940), and Szentagothai and Cajal (1948). The second pathway is to continue into the cerebellum and then on to the cerebral cortex where the impulses can be mediated on a conscious level. The impulses that synapse to the motor nucleus of the trigeminal, as pointed out by Corbin and Harrison, are probably of an inhibitory function, thus being protective and preventing damage to the teeth and gingivae.

The means used to study the effect of sensory input on the motor output to the masticatory muscles in this investigation was electromyography.

B. Review of the Longitudinal Study

Electromyographic recordings were taken of the temporal and masseter muscles on sixteen patients with varying types of malocclusions before treatment was begun and at various treatment stages. The first three chewing strokes of two chewing exercises of the right and left temporal and masseter muscles were recorded electromyographically for each subject during each treatment stage. These myograms were then analyzed employing various methods of study.

It is important at this time to described the phases of orthodontic treatment, to fully appreciate the findings in this longitudinal study.

Widen (1960, Part I, Experiment I), recorded the muscular activity during mastication in the original malocclusion and then in Experiment II recorded the muscular activity one day after the placement of separating wires between the teeth. He then compared the myograms of both experiments considering each subject as a separate experimental unit unto himself. The separating wires were made of brass and were inserted between the teeth, wrapped around the contact points, and then twisted tightly in order to create enough space between the teeth to permit the placement of orthodontic bands on all of the teeth. Widen found a definite change in the behavior patterns of the temporal and masseter muscles twenty-four hours after the placement of separating wires between the teeth and that there was an increase in the duration of the chewing stroke in seven of the sixteen subjects.

Asahino (1960, Part II, Experiment III), in comparing myograms taken one week after the placement of separating wires between the teeth with those taken on the original malocclusion, showed less variability with the original records than Experiment II and attributed this to adaptation on the part of the neuromuscular mechanism.

Shanahan (1960, Part III, Experiment II), compared myograms taken one week after the placement of the first archwires with the pretreatment records. During the time between this experiment and the last experiment (Experiment III) the separating wires were removed and orthodontic bands were cemented onto the teeth and then the first orthodontic archwires were placed. These archwires begin to initiate tooth movement and change the axial inclination of the teeth and also the relation of the opposing occlusal surfaces of the teeth to each other. Shanahan found an altered pattern of muscular behavior as compared with Experiment I and that the subjects in Experiment IV that showed a change in muscular behavior presented myograms with an increase in the duration of the chewing stroke and in the number of bursts of electrical activity. He also found that the initiation of chewing activity on the part of the temporal, especially the posterior temporal, increased while that on the part of the masseter decreased. He attributed these changes to altered periodontal proprioception. These findings indicate that the subjects were using more caution during mastication, since the number of bursts indicate the number of times inhibition had taken place, and an increase in the duration of the chewing stroke indicated that the subjects were chewing with more caution. The lessened participation on the part of the masseter in initiating chewing activity is logical too, as the main function of this muscle is power, which was not needed at this time.

Zylinski (1961, Part IV, Experiment V), compared myograms taken during anchorage preparation (six to eight weeks after placement of the first archwires) with the pretreatment records. However, rather than comparing just these two stages of treatment, Zylinski and Fleming re-evaluated all of the data from the previous experiments because at this time there was sufficient data to employ meaningful statistical analysis. This meant that, not only did they compare each subject with himself during the different stages of treatment as the original three investigators did, but they pooled the data from all sixteen subjects in each experiment and compared the different experiments with one another. This, in essence, was a comparison of muscular activity during the different stages of orthodontic treatment. This reappraisal of the previous data brought out statistically, that the greatest number of bursts in a chewing stroke, and therefore the greatest amount of inhibition up to that time occurred in Experiment III (Asahino) one week after the placement of separating wires between the teeth. Zylinski attributed this to the pain caused by the damage to the periodontal ligament created by this excessive force and since pain takes the "final common pathway" in precedence over proprioception, the inhibition that occurred was a result of this pain.

During the time that had intervened between Experiment V and Experiment IV the posterior teeth had been uprighted and the anterior tooth position and alignment had been changed. Zylinski found a small increase in the number of bursts, a definite increase in the duration of the chewing stroke and a marked increase in the occurrence of synchronous initiation of the chewing activity as compared to the first experiment. He concluded that pain was far more instrumental than proprioception in obvious changes in the motor behavior of the masticatory muscles and that there was a change in the division of labor between the masseter and temporal muscles, the temporals becoming more active and the masseters becoming less active in initiation of chewing activity as treatment progressed.

Fleming (1961, Part V, Experiment VI) compared the myograms taken at the completion of anchorage preparation (twelve to sixteen weeks after the placement of the first archwires) with all the myograms taken up to that point in the longitudinal study, as well as with those taken in Experiment I. At this stage of orthodontic treatment the posterior teeth had been uprighted and tipped distally, the maxillary teeth being tipped distally approximately five degrees from the perpendicular and the mandibular teeth approximately eight degrees distally from the perpendicular for the purpose of opening the occlusal vertical dimension. Fleming found a decrease in the number of times synchronous activity of the three muscles initiated the chewing cycle, from Experiment V, which he attributed to the distal tipping of the previously uprighted posterior teeth, a decrease in the participation on the part of the masseter muscles and an increase in the participation on the part of the middle and posterior temporal muscles in the initiation of chewing activity and an increase in the duration of the chewing stroke all of which he attributed to painful experiences during mastication. He also concluded that the number of bursts in a chewing stroke is a reasonable indication of the number of times inhibition had taken place in the muscles being studied.

This part (Part VI, Experiment VII) of the longitudinal study concerned itself with the final stages of orthodontic treatment. It is necessary to explain here, that this part of the study differed from the other previous parts in that, up to this time each subject was at the same stage in treatment when records were taken for each experiment, but during the time the electromyographic recordings were taken in this experiment the subjects were in different final stages of treatment. Some of the subjects already had the appliances removed (four subjects) and were on functional retention, while the remaining (twelve subjects) were still wearing the active appliances. Of the twelve subjects wearing the active appliances six subjects were at the stage of correcting the Class II molar relation, four subjects were at the stage of consolidation of the spaces between the anterior teeth, and two subjects were at the stage of lingual tipping of the roots of the upper incisor teeth ("torquing").

During the final stages of treatment the mandibular teeth had less of a disto-axial inclination than at the completion of anchorage preparation (Experiment VI) due to the mesial and upward force placed on them from the Class II type elastics, as all subjects at this time, either had already worn these elastics or were still wearing them. The fact that the mandibular teeth were more upright at the time recordings were taken in this experiment would mean that there was less occlusal interference due to cusp to cusp relation of upper posterior with lower posterior teeth and therefore less pain and tenderness in the posterior teeth. The exception to this would be in those cases in which the Class II molar relation was being corrected and the maxillary and mandibular molars were riding cusp to cusp or almost cusp to cusp as the distal inclined planes of the maxillary first molars were being moved distally up the mesial inclined planes of the mandibular first molars. At this stage only the molar teeth would be in occlusal contact and would be bearing the brunt of the occlusal force during mastication, thus, we would expect to find the sensory input from the periodontal ligament of these teeth to have a marked effect (inhibitory, protective) on the motor output of the temporal and masseter muscles.

In those subjects whose teeth were undergoing space closure, or consolidation of the mandibular and maxillary anterior teeth, the Class II molar relation would have already been corrected and there would be a more normal inclined plane relation between the mandibular and maxillary posterior teeth with more teeth bearing the force from occlusion during mastication. The posterior teeth at this time would also be in a more ideal axial inclination mesiodistally, thus, there would be a tendency to have fewer occlusal interferences or cuspal interferences and the force from occlusion during mastication would be distributed over a greater number of teeth. This would mean that the subjects were undergoing less pain and discomfort during mastication and that chewing, once initiated would be under the control of reflex from impulses from the proprioceptors in the periodontal ligament rather than by impulses from the pain receptors (which, as shown by Zylinski, 1961, take precedence over the proprioceptive impulses in the "final common pathway", causing the muscular movements to be on a more conscious level.)

In those cases in which the upper anterior teeth were having their roots tipped lingually (torqued) there would be the same relation of the posterior teeth (mandibular and maxillary) to each other as in the previous instance.

In the subjects who already had the active orthodontic appliances removed, the tooth to tooth relation and inclined plane to inclined plane relation is markedly improved. The reason for this being that when appliances are on the teeth and an archwire placed in the brackets it is virtually impossible to have the teeth and inclined planes in perfect occlusal interdigitation due to the discrepancy of bracket height on the teeth in relation to cuspal and ofssa height. Once the orthodontic appliance is removed and functional retention instituted the teeth are permitted to "settle" into occlusion through function creating a more nearly perfect cusp to fossa and inclined plane to inclined plane relation. In addition to this the posterior teeth tend to assume a more favorable axial inclination, mesiodistally due to the angle of the occlusal surfaces in relation to the roots of the teeth thus, causing the crowns of the posterior teeth to move mesially until their long axes are parallel to the force of occlusion. This being the case, we would expect a minimum of interferences in the occlusion and that chewing, once initiated would be under the control of reflexes (Sherrington, 1917) by impulses from the periodontal proprioceptors, showing a pattern of muscular activity which would exhibit less inhibition.

These axial changes and occlusal changes in the position of the teeth, as shown by Jarabak, 1954, Moyers, 1950, Perry, 1955, Widen, 1960, Asahino, 1960, Shanahan, 1960, Zylinski, 1961, Fleming, 1961, and others, alter the input to the sensory receptors (proprioception, touch and pain) in the periodontal ligament and since these regulate, in a large measure, the motor behavior of the temporal and masseter muscles, it was felt that changes in the electromyographic behavior of the muscles would occur, as orthodontic treatment and tooth movement progressed.

C. Interpretation and Evaluation of the Findings

Listing and Evaluating the Characteristics of the Myograms for each Individual Subject in Experiments I through VII.

The object of this method of study was to note the changes in the electromyographic behavior of the muscles for each individual subject during the various stages of orthodontic treatment and to see if any general trends would evolve in the pattern of muscular behavior from experiment to experiment or, as it were, from treatment stage to treatment stage. As this method was the method of study employed by the first three investigators (Widen, Asahino and Shanahan, 1960) in this longitudinal study, when each subject was considered a separate experimental unit unto himself, the author felt that this should be continued to observe what happened to the muscular behavior of each individual as treatment progressed. It was hoped that some general trend may evolve and that the exceptions to this trend could be explained, thus, adding to a better understanding of the nature of occlusion and its effect on the muscles that move the mandible.

Each of the characteristics that were evaluated gave some clue as to what was happening to the muscles during the various treatment stages. Amplitude, although affected by many variables, gave some indication of the magnitude of force that was employed in masticating the cough drop, the number of bursts and nodes (as shown by Fleming, 1961) is a reasonably good indicator of the number of times inhibition has taken place during the chewing stroke, the rate of onset and rate of ending of activity gave some indication as to the type of chewing stroke used (as Pruzansky, 1952 showed, the short ballistic type of chewing stroke with a rapid buld up and rapid decline was characteristic of those occlusions in which there was interference in the cuspid region preventing lateral excursions), duration of chewing stroke could show the relative amount of time the subject had his jaws actively closing, sustained low amplitude was an indication of any spasmodic activity in the muscles being studied, interim activity could be attributed to the myotatic, or stretch reflex when the jaws were opened maximally these may well be stabilizing contractions as described by MacDougall and Andrew, 1953, and initiation of chewing activity gave an indication of the division of labor between the muscles being studied.

In general, most of the subjects showed more inhibition and less synchrony in initiation of chewing activity from the time of the original malocclusion through the placement of the first archwires, with one week after the placement of the separating wires showing the greatest change in the muscular behavior and the greatest amount of inhibition as shown by Fleming and Zylinski, 1961. This can be explained by the fact that in most instances in the original malocclusion, the teeth were in a position dictated by function and the learned behavior pattern of the musculature caused the mandible to circumvent occlusal interferences. The orthodontic movement of these teeth upset the neuromuscular equilibrium. These two characteristics of the myograms (synchrony and inhibition or noding) gave the best indication of changes taking place in the behavior of the musculature.

Again, for most of the patients, there was a change in the behavior pattern of the muscles being studied during anchorage preparation where the posterior teeth were being uprighted and tipped distally. During this time the electromyograms showed less inhibition, more synchrony in initiation of chewing activity and a slight increase in amplitude. This could be attributed to the fact that in most malocclusions the molar teeth are in a mesio-axial inclination and during the time electromyographic recordings were taken for that part of the study these teeth had been uprighted to a more normal axial inclination. Another fact too, that should not be overlooked is that the damage to the periodontal membrane done by the separating wires had probably been reparied by this time and, thus, the painful experiences during mastication had also disappeared so that once again the periodontal proprioceptors were guiding the mandibular musculature by means of the two-neuron reflex arc in the mesencephalic root of the trigeminal nerve. This was pointed out by Zylinski and Fleming (1961), in Parts IV and V of this study.

In general, for most of the subjects, the muscular pattern of behavior began to become more unfavorable after the anchorage preparation was completed, as shown by Fleming (1961), and there was more inhibition and more of a "searching pattern" (described by Perry, 1955) during mastication because at this stage of treatment the mandibular molars had been tipped distally so that the mandibular and maxillary molars were striking cusp to cusp and were in most instances, the only teeth in occlusal contact, and therefore, exhibiting pain and tenderness during mastication, and bringing mandibular movements under conscious control.

During the final stages of treatment, in those cases where the Class II molar relation had already been corrected there was a decrease in the number of times inhibition had taken place, an increase in the number of times there was synchronous initiation of chewing activity and an increase in amplitude, and even in some cases a disappearance of sustained low amplitude activity which had been present previously, in some of the muscles.

Those subjects who were still under going Class II molar correction showed, for the most part no obvious change in the pattern of muscular behavior as compared with the previous stage of treatment.

These generalizations held true in almost all instances except in two subjects, namely, subjects number eight and sixteen. Subject number eight was a two upper first bicuspid extraction case with no teeth extracted in the mandibular arch. Subject number sixteen, before treatment was begun, had both mandibular first molars missing, and for treatment purposes the two upper first bicuspids were extracted. Both of these subjects were being treated to a full Class II molar relation, that is, the disto-buccal cusps of the maxillary first molars were seated into the buccal groove of the mandibular first molars (or as in the case of subject number sixteen, into the buccal groove of the mandibular second molar, as these second molars were brought forward into the mandibular first molar position). These teeth were not designed by nature to occlude in this relation and occlusal interferences probably altered the periodontal proprioception in these cases causing the temporals to initiate chewing activity as these are the muscles that guide the mandible into position during mastication. It will be interesting to see if the pattern of muscular behavior will be altered after these two cases have had the active orthodontic appliances removed.

Up to this point in the orthodontic treatment, we can see that a change in the axial inclinations of the teeth does affect the motor output to the muscles of mastication (temporal and masseter muscles) as pointed out by Jarabak, 1954, Moyers, 1950, Fleming and Zylinski, 1961, and others. The change in the muscular behavior pattern being a tendency to exhibit more inhibition and caution in mastication when the periodontal ligament has been damaged as when separating wires were placed between the teeth or when the mandibular posterior teeth have been uprighted and distally tipped causing a cusp to cusp relation of the mandibular and maxillary first molars which in turn caused them to bear the "load" of the occlusal forces during mastication and become painful and tender, or when a similar situation exists as during the correction of the Class II molar relation. The behavior of the muscular pattern improved, or the subjects "adapted" six to eight weeks after anchorage preparation was started (Zylinski, 1961) because the teeth were in a "more normal" axial inclination than they had been previously. (By "more normal" it is meant that the axial inclination of the teeth was such, that they were parallel to the forces of occlusion thus transmitting these forces to their periodontal ligaments as a tension rather than as a pressure on the periodontal ligaments in certain areas and also as a pressure on the cribiform plates of the alveoli. When the teeth have their long axes parallel to the forces of occlusion this also permits their cusps and fossae to interdigitate correctly because of the angle between the occlusal surfaces and the long axes of the teeth.) The same held true during the final stages of treatment as, once again, the axial inclinations and interdigitation of the teeth presented less occlusal interferences allowing proprioception rathern than pain and therefore reflexes rather than conscious control to govern the mandibular movements.

Analysis of the Initiation of Chewing Activity

The object of this method of study was to ascertain any trends that may have occurred in the division of labor between the different muscles, or muscle groups being studied. All possible combinations of these three muscle pairs were studied. The trend seemed to indicate an increasing participation of the part of the combination of the middle and posterior temporal muscles, from Experiments I through VI, but in Experiment VII the trend changed and although initiation of the chewing cycle on the part of the masseters continued to decrease, so did initiation of the chewing cycle on the part of the middle and posterior temporals. It was at this point that the concurrent activity of all three pairs of muscles took over the initiation of chewing activity. The remaining four combinations of muscles showed little change throughout treatment, except for the posterior temporal alone which increased only during anchorage preparation and then dropped to its previous range after anchorage preparation was completed.

To understand this phenomenon one must first taken into consideration the function of the muscles involved. Since the temporal and masseter muscles have different primary functions (positioning, and power), it was believed that the changing occlusal relations of the teeth during orthodontic treatment might possibly cause a change in the functional requirements of the mandibular musculature. For example, if more power is needed for the masticatory stroke, the masseter muscles will be the muscles called upon to provide the power. Therefore, they would be expected to begin activity earlier than if ther power function was not needed.

According to Moyers (1950), the masseter initiates chewing activity in most Class II Division 1 malocclusions and this is exactly what has been shown here since most of the subjects in this study presented with Class II Division 1 malocclusions. The decrease in the number of times the masseters initiated chewing activity from the beginning of treatment and the increase in the number of times the middle and posterior temporals initiated chewing activity is explainable because as treatment progressed there were certain stages of treatment where occlusal interferences were created and where the teeth became sore and tender as described previously. In these instances the power function of the masseter was not needed. Only in those instances during orthodontic treatment where the axial inclinations and interdigitation of the teeth was good (for instance, during anchorage preparation, where the posterior teeth were uprighted from their previous mesio-axial inclinations) did the masseter come into play and then this was in synchrony with the middle and posterior temporals. This was shown in Experiment VII during the final stages of orthodontic treatment where the axial inclinations of the teeth and occlusal interdigitation was more favorable than at any other time during treatment, initiation of chewing activity on the part of the masseters alone and the temporals alone dropped off sharply but synchronous or concurrent initiation of activity of all three muscle pairs increased sharply.

The muscle combinations studied that did not show any change or minimum change during treatment can be explained on the basis that they were combinations of either middle or posterior temporal with the masseter or the posterior temporal alone, and since only one fraction alone of the temporal does not normally or physiologically work by itself (with the exception of the posterior temporal) and the masseter does not work only with one portion of the temporal, these combinations remained minimal in initiation of activity throughout the study. At one point however, the initiation on the part of the posterior temporal did increase. This was during anchorage preparation.

Whenever the axial inclinations and inclined plane relation of the teeth was such that the forces of occlusion were parallel to the long axes of the teeth the sensory receptors interpreted this as meaning that a more satisfactory axial inclination of the teeth had been attained. These two factors, expressed by impulses from the sensory receptors in the periodontal ligament and integrated by the mesencephalic root of the trigeminal nerve, reflexly controlled mastication by efferent impulses to the masseter and temporal muscles (Sherrington, 1917). On the other hand, whenever occlusal interferences were present and the teeth were tipped to an axial inclination whereby the forces of occlusion were not parallel to the long axes of the teeth, masticating on a hard substance such as the cough drop probably stimulated the pain receptors in the periodontal membrane. These pain impulses, mediated by the spinal nucleus of the trigeminal nerve and integrated with other afferent impulses in the post-central gyrus of the cerebral cortex, caused the trigeminal motor nucleus to alter the efferent impulses to the masseter and temporal muscles. This was the manner in which the nervous system prevented the experience of additional painful stimuli. A similar inhibitory mechanism was operating over the two-neuron reflex arc mediated by the mesencephalic root of the trigeminal nerve. The inhibition mediated in the mesencephalic root was also a protective mechanism preventing damage to the teeth and surrounding structures. Through the medium of these two pathways (pain and proprioception) the efferent stimuli to the masseter and temporal muscles were altered (Corbin and Harrison, 1940, and Szentagothai, 1948).

Analysis of the Duration of the Chewing Stroke (Biting Stroke) Expressed as a Percentage of the Chewing Cycle.

The object of analyzing the chewing stroke or biting stroke as a percentage of the chewing cycle in each experiment for all sixteen subjects was to see what effect, if any, the different stages of orthodontic treatment had on the length of the chewing stroke or biting stroke to see what the trend was as orthodontic treatment progressed. Using the Chi Square Test to evaluate the data, significant differences were found to exist between the distributions of the different durations of the chewing strokes or biting strokes in all of the experiments up to this time. In addition to this significant differences were found to exist for the distributions of these durations between Experiments I and VII and VI and VII. All this would mean is that the distribution of the frequency of occurrence of the various percentages (percentages of the length of the chewing strokes or biting strokes in relation to their chewing cycles) changed in shape from experiment to experiment. This is evident when one looks at the histograms made from these data for each separate experiment (see pages 207 to 210 Graph II in Part III of "FINDINGS"). In looking at these histograms we can see that the distribution of these percentages does change, as the base of the histograms becomes narrower up to Experiment III. In Experiments IV and V the base becomes wider, but not as wide as in Experiment I. In Experiment VI the base of the histogram becomes narrower again and then broadens slightly in Experiment VII. The greatest frequency of occurrence throughout the entire study is of the percentages (of the chewing stroke or biting stroke) between 45%

and 65% as shown on these histograms.

In analyzing what is happening here, it must be taken into consideration that as one percentage range increases, one or some of the others must decrease. It is evident that as treatment progresses, the shortest chewing strokes or biting strokes (0-15% and 15-25%) decrease in frequency of occurrence or disappear entirely, the logical conclusion being that as orthodontic treatment progresses the chewing strokes or biting strokes become longer and in previous experiments this was attributed to inhibition occurring during mastication. But, as pointed out before, the greatest frequency of occurrences was of those percentages (of the chewing stroke or biting stroke) between 45% and 65%. The frequency of this range of percentages (of the chewing stroke or biting stroke) remained high throughout the entire study from Experiment I through Experiment VII. In Experiment III it reached its highest point. This percentage range also accounted for the majority of percentages in Experiment I (The Original Malocclusion). The very longest percentages fluctuated throughout the entire study, but did not show any trend and remained approximately within the same range of frequency of occurrence. Now, if the length of the chewing stroke or biting stroke tended to increase as a result of inhibition in the muscles during mastication then we would expect to find a much longer chewing stroke or biting stroke in the experiment, or treatment stage, in which the muscles exhibited the greatest amount of inhibition and a shorter chewing stroke in the experiment, or treatment stage, in which the muscles exhibited the least amount of inhibition. This did not occur. These were Experiments III (One Week After the Placement of Separating Wires Between the Teeth) and VII (During the Final Stages of Treatment) respectively. In these two experiments the greatest frequency of occurrence was of those percentages between 45% and 65%. The only explanation for this phenomenon would be that a long, hard chewing stroke or biting stroke, one that would have a forceful and definite biting pressure, where the subject would bite entirely through the chewing medium, may be as long as an indefinite, searching and inhibited chewing stroke or biting stroke, where the subject could not bite through the chewing medium. It must, therefore, be concluded that the length of the chewing stroke or biting stroke expressed as a percentage of the chewing cycle is not a reliable indicator of the amount of inhibition taking place in the muscles being studied during the act of mastication. It is a possibility, from the picture presented by these histograms, that the habitual length of the chewing stroke or biting stroke is between 45% and 65% of the entire chewing cycle and it does not seem to be affected by sensory reception from the periodontal ligament so that regardless of the amount of caution exhibited during mastication, when the jaws have been actively closed 45%-65% of the chewing cycle they are opened, in much the same manner that the number of chews given a bolus of food is determined by habit regardless of the efficiency of the dentition as shown by Paulsen and Clausen, or as Dahlberg showed, the habits of mastication remain the same after the loss of teeth.

The disappearance of the shortest chewing strokes or biting strokes from the time of the original malocclusion as treatment progressed could be explained on the basis of Pruzansky's (1952) findings, where he showed that in cases of interference in the cuspid region, preventing lateral excursions the chewing stroke was of a "chopping" nature showing up electromyographically as a myogram with a rapid build up and rapid decline. The frequency of occurrence of these very low percentages was small and could be attributed to those subjects having Class II canine relations that were prevented from going into lateral excursions, this condition being corrected as orthodontic treatment progressed.

Analyzing the Number of Bursts in a Chewing Stroke (Biting Stroke)

The object of analyzing the number of bursts in a chewing stroke or biting stroke, was to ascertain if there was a statistically significant difference between the amount of inhibition occurring in the temporal and masseter muscles during the chewing strokes of those subjects still wearing appliances and those who already had the appliances removed. Fleming (1961) concluded that the number of bursts in a chewing stroke was a reasonably good indication of the number of times inhibition had taken place in the muscles studied.

It should be mentioned here that Fleming (1961) did not prove the above conclusion, but that this was a logical deduction based upon the electromyographic recordings he obtained. This author agrees with Fleming on the basis that since the number of bursts of electrical activity in a chewing stroke or biting stroke is dependent upon the number of nodes (areas of brief low or zero amplitudes during the biting stroke) and these nodes most probably represent a slowing or "braking" action of the masseter and temporal muscles during biting, the number of bursts (or for that matter the number of nodes) in a chewing stroke or biting stroke could possibly represent inhibition in the muscles during mastication.

It can be argued that "nodes" could be due to the fact that the recording electrode is small and that it is placed on only one small area of the muscle and that this phenomenon of "noding" appearing on the myogram may be due to cessation of activity in the part of the muscle directly under the electrode while activity was still proceeding in a different part of the muscle too far away for the electrode to pick up the a ction potentials. If this were true, that an alternate firing of muscle fibers took place in different parts of the muscle at such a low frequency during mastication, then it would be virtually impossible to obtain a tracing of a chewing or biting stroke on the electromyogram without a node. Since many chewing or biting strokes were obtained that were of single bursts of electrical activity without noding, the above argument can be refuted. Therefore, the author assumes that the most logical explanation for the presence of these nodes in the myogram during mastication is that they are an indication of inhibition taking place in the muscle during the act of biting through the chewing medium and that the number of nodes or bursts of electrical activity in the chewing or biting strokes is an indication of the number of times inhibition has taken place.

The comparison was made between these two groups of subjects in Experiment VII, four of the subjects already had the appliances removed. The findings indicated that a statistically significant difference did exist between these two groups at the .001 level of significance. This would mean that there was a very significant difference in the amount of inhibition occurring in the chewing strokes between those patients undergoing active treatment and those whose appliances were removed and were on functional retention. This is largely what would be expected because after the appliances have been removed there is a more favorable axial inclination of the teeth and less occlusal interferences. Also the irritation of the supporting structures of the teeth was reduced because of the removal of the appliance. All these factors allowed the act of mastication, once initiated, to be under the control of the reflex mechanism of the two-neuron reflex arc of the mesencephalic nucleus of the trigeminal nerve, in those subjects no longer wearing appliances.

CHAPTER V

SUMMARY AND CONCLUSIONS

A. Summary

This study was the sixth part of a longitudinal electromyographic investigation to determine what effect a change in sensory input to the periodontal sensory receptors (pain, pressure and proprioception), due to orthodontic tooth movement, had on the motor output to the temporal and masseter muscles. Electromyographic recordings were taken before, during and after orthodontic treatment.

The orthodontic procedures used in this study are distinguished from other orthodontic procedures, in that, light forces generated from highly resilient small diameter wires and light latex elastics were used as a means to effect tooth movement.

Sixteen subjects presenting varying types of malocclusions (three neutrocclusions and thirteen distocclusions) constituted the heterogenous experimental group. The first three chewing strokes of two chewing exercises of the right and left temporal and masseter muscles (considering the ipsilateral side only) were recorded electromyographically for each subject during each treatment stage. These electromyograms were then analyzed, studying various characteristics and employing a number of methods of study. The chewing medium used was Vicks cough drops.

This part of the study dealt with the electromyographic recordings taken during the final stages of orthodontic treatment. This was defined as the correction of the Class II molar relation (in distocclusion cases), space closure between the anterior teeth (consolidation), lingual tipping of the roots of the maxillary anterior teeth ("torquing") and the final "seating" of the cusps and inclined planes of the teeth into occlusion.

The findings from this part of the study (during final stages of orthodontic treatment) were compared with the findings previously obtained by the earlier investigators in this longitudinal study for the purpose of ascertaining any trends that may have occurred in the behavior patterns (detected electromyographically) of the muscles being studied, during orthodontic treatment. Electromyographic recordings were taken this far in the longitudinal study during the following stages in the treatment of these malocclusions:

Experiment I	Original Malocclusion.
Experiment II	One Day After Placement of Separating Wires Between the Teeth.

Experiment III   One Week After Placement of Separating Wires Between the Teeth.

Experiment IV   One Week After Placement of the First Archwire.

Experiment V   During Anchorage Preparation.

Experiment VI   After Completion of Anchorage Preparation.

Experiment VII   During the Final Stages of Orthodontic Treatment.

Additional electromyographic recordings will be taken and analyzed by other investigators to treatment completion in order to complete this longitudinal study.

B. Conclusions

1. Greater inhibition, as indicated by nodes and bursts, was exhibited by the temporal and masseter muscles, in the act of mastication, during any treatment stage where the long axes of the teeth were not parallel to the forces of occlusion or where occlusal interferences existed.

2. Damage to the periodontal ligament, from any cause, resulting in pain tends to cause the greatest amount of inhibition in the temporal and masseter muscles during mastication.

3. The electromyographic behavior pattern of the muscles studied

improves markedly during the final stages of orthodontic treatment after the Class II molar relation (or distocclusion) has been corrected. This is shown by a decrease in inhibition (or noding) and an increase in concurrent initiation of chewing activity by all three muscle pairs studied.

4. During the final stages of orthodontic treatment there is a definite change in the division of labor between the masseter and temporal muscles, as shown by the large increase in synchronous initiation of chewing activity by these muscles. The trend up to this point had been one of decreasing participation on the part of the masseters and increasing participation on the part of the middle and posterior temporal muscles. At this point the masseters became more active in initiation of chewing activity, but in conjunction with the temporals.

5. There is a tendency for the majority of the chewing strokes or biting strokes to be between 45% and 65% of the chewing cycles. This may well be the habitual length of the chewing stroke or biting stroke.

6. The very short chewing strokes or biting strokes (0 to 25%) tend to disappear as orthodontic treatment progresses. This is probably due to the correction of cuspid interferences which had been present previously and prevented lateral excursions and resulted in a "chopping" like chewing

stroke, by some of the subjects in the earlier experiments.

7. The length of the chewing stroke or biting stroke is not a very reliable indicator of the amount of inhibition taking place in the masseter and temporal muscles during mastication, because it does not vary in proportion to the amount of inhibition exhibited during the chewing stroke.

8. There is a statistically significant decrease in the amount of inhibition (as indicated by bursts and nodes) taking place in the temporal and masseter muscles, during mastication, after orthodontic appliances are removed.

9. Those subjects being finished in a full Class II molar relation exhibited more inhibition (or noding) during mastication in the final stages of orthodontic treatment, than those being finished in a Class I molar relation (neutrocclusion).

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APPROVAL SHEET

The thesis submitted by Dr. Ronald H. Roth has been read and approved by members of the Departments of Anatomy and Oral Biology.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

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